Safe manriding in mines
First Report of the National Committee for Safety of Manriding in shafts and Unwalkable Outlets

The National Committee

A National Committee for Safety of Manriding in Shafts and Unwalkable Outlets was formed and first met on 3 December 1973. The persons who served on this committee were:

Chairman  
W J Currie  Director of Engineering, National Coal Board,  
Mr Currie retired on 31 March 1974 and was succeeded by:

J D Blelloch  Director of Engineering, National Coal Board, who had previously been a member of the committee as Chief Mechanical Engineer for the National Coal Board.

Deputy Chairman  
S Luxmore  HM Principal Electrical Inspector of Mines and Quarries, Health and Safety Executive.

Members  
T K Clancy  HM Principal Inspector of Mechanical Engineering in Mines and Quarries, Health and Safety Executive.

H M Harrison  Mechanical/Electrical Inspector, National Union of Mineworkers.

R Hartill  Chief Electrical Engineer, National Coal Board

E Lownes  Representing the Association of Mining Electrical and Mechanical Engineers.

H D Munson  Head, Engineering Group, Safety in Mines Research Establishment, Health and Safety Executive.

A Rushton  Representing the British Association of Colliery Management.

L Walker  Director of Plant and Workshops, National Coal Board.

J N L Woodley  Deputy Director (Project Development), Mining Research and Development Establishment, National Coal Board.

Secretary  
R F Young  HM District Inspector of Mines and Quarries, Health and Safety Executive.

This is a web-friendly version of Safe manriding in mines: First Report of the National Committee for Safety of Manriding in shafts and Unwalkable Outlets, originally produced by HM Inspectorate of Mines.
Foreword

In his report following the public inquiry into the winding accident at Markham Colliery, Derbyshire (Cmnd 5557), Mr J W Calder CBE, then HM Chief Inspector of Mines and Quarries, referred to the formation of a committee to consider all safety aspects of manriding in shafts and unwalkable outlets. In view of the wide scope of the investigations the committee planned to execute its task in stages. The first part of the report deals with shaft winding practices and examines the aspects of design, construction, operation and maintenance of winding engine brake gear, automatic contrivances and the ancillary safety equipment associated with winding engines, headframes and shafts which are essential to safety. It further examines lift practices and certain overseas shaft winding practices, and offers a comprehensive guide to all those concerned with the safe winding of persons in mine shafts.

Part 1A covers the various principles involved, together with the committee’s conclusions and recommendations for future action. Part 1B contains the supporting technical information and, in certain cases, recommended methods of applying the principles in practice.

In the meantime, the Committee remains in being to continue its work, and further reports will be submitted.

J CARVER

HM Chief Inspector of Mines and Quarries

Note: The Mines and Quarries Inspectorate is now part of the Health and Safety Executive, consequently Mines and Quarries forms referred to in the text will in future be issued by the Health and Safety Executive.
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PART 1A

Principles and recommendations for shafts
Introduction: the accident at Markham Colliery

Markham Colliery is a large producing mine in the North Derbyshire area of the National Coal Board at which a serious overwind occurred at the Number 3 upcast shaft on 30 July 1973, while the dayshift was being lowered. The descending double deck cage carrying 29 men crashed on wooden baulks at the pit bottom with the result that 18 men died and the remaining 11 were seriously injured. The ascending cage was empty and was wound into the headframe and parted from the rope by operation of the detaching hook in the headframe bell. This cage continued to ascend until it struck the roof girders of the airlock structure but the detaching hook was correctly captivated in the headframe bell and the cage was held by its suspension chains when it fell back. The momentum of the winding system unwound the spare coils of the descending overlap rope: the capel by which it had been anchored to the drum was torn away: together with parts of the drum side and brake path, and the rope and its capping were pulled over the headframe pulley and fell down the shaft partly on top of, and partly alongside, the cage containing the men. The capel of the detached ascending under-lap rope was pulled into the engine house where it did considerable damage.

The 440 hp (330 kW) electric winding engine was of the DC Ward Leonard type (as under category V of paragraph 27(1)). The wind had proceeded normally until the cages had passed the mid point in the shaft, at which stage the winding engineman began to slow the system down by braking electrically. Hearing a bang from the vicinity of the mechanical brake engine, he moved the electrical control lever more towards the off position, to reduce speed further, and also tried to apply the mechanical brake by using the service brake lever. The mechanical service brake lever had no effect and he pressed the emergency stop push button which cut off all power. The mechanical brake should then have been applied automatically, but was not, and no electrical braking remained available as the supply to the winding engine had been cut off. As a result, there was no means by which the winding engineman could arrest the cages.

The cradle type mechanical brake consisted of two lined shoes applied to the undersides of the brake paths at each end of the drum by action of a compressed spring nest operating through a system of levers. The winding engineman’s service brake lever controlled mechanical brake movement by use of compressed air to counteract the force of the spring nest but the brake could also be applied automatically by pressing the emergency stop push button. Force from the spring nest was transmitted to the main lever of the brake system by a vertical 2 in (51 mm) diameter steel rod 8 ft 11 7/8 in (2.74 m) long, located in the centre of the spring nest, constrained by a plate at the top of the springs and connected through a distance piece and a crosshead trunnion to the main lever at the bottom (fig 1). Investigation revealed that the main lever and crosshead trunnion axle were unable to move freely with respect to each other when the brake was operated. As a result, the 2 in (51 mm) diameter spring nest rod flexed during each brake application and finally, after 21 years, failed from fatigue at the threaded portion inside the distance piece. The disaster was caused because the spring nest rod was a single line component whose failure rendered the mechanical brake of the winding engine inoperative.

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1 See glossary: The first time a term defined in the glossary appears in a subsection it is printed in italics.
Figure 1 No 3 shaft Markham Colliery: arrangement of spring nest centre rod and brake system main lever

Public inquiry

During October 1973, the Public Inquiry into the accident, held at Chesterfield by Her Majesty’s Chief Inspector of Mines and Quaries as Commissioner, lasted for six days and 55 persons gave evidence. The interested parties represented were:

The Inspectorate of Mines and Quaries (then the Department of Trade and Industry, subsequently the Department of Energy and now the Health and Safety Executive);
The National Union of Mineworkers;

The National Association of Colliery Overmen, Deputies and Shotfirers;

The National Coal Board;

The British Association of Colliery Management; and

The National Association of Colliery Managers Limited.

From the evidence given at the Inquiry, the Commissioner was able to determine the cause and circumstances of the overwind. The report on the Accident at Markham Colliery, Derbyshire, which includes conclusions and recommendations, was published by Her Majesty’s Stationery Office in April 1974 Cmnd 5557 (hereinafter referred to as the Markham Official Report).

**National Committee and terms of reference**

During the course of the Inquiry it became evident that there was an urgent need for a committee of engineers to consider all safety aspects of manriding in shafts and unwalkable outlets. Immediately after the Inquiry the Commissioner met representatives of the interested parties who agreed that a National Committee should be formed; the names of the members of the Committee are given at the beginning of this report. The terms of reference given to the Committee by the Commissioner were TO CONSIDER ALL SAFETY ASPECTS OF MANRIDING IN SHAFTS AND UNWALKABLE OUTLETS AND TO MAKE RECOMMENDATIONS.

**Formation of sub-committee and working groups**

At the first meeting of the National Committee, four sub-committees were formed to consider the engineering aspects of its investigations as follows:

- No 1 Mechanical
- No 2 Electrical
- No 3 Maintenance
- No 4 Metallurgy and materials

Shafts in the course of being sunk were excluded.

The sub-committees decided that their investigations should take account of all aspects of winding and shaft activities (other than at shaft sinkings) which could affect the safety of manriding and their first task was to define appropriate terms of reference to enable the National Committee to discharge its mandate. It was soon apparent that the extent of the work was formidable and that it would take several years to consider fully all aspects and prepare a report. It was recognised also that a substantial report should be produced as quickly as possible and consequently it was decided to publish the report in parts and that Part 1 should include priority items. Each sub-committee therefore established the following working groups to examine the technical aspects of the priority subjects listed below:

**Mechanical**

- No 1A, design principles of winding engine brake gear.
- No 1B, safe operation and statutory testing of winding engines.
- No 1C, auxiliary equipment for winding engines and passenger lifts.
Electrical

No 2A, electrical protection.
No 2B, electrical control and braking.
No 2C, push-button winding.
No 2D, shaft and headframe equipment.
No 2E, passenger lifts.

Maintenance

No 3A, appraisal of winding engine maintenance in practice.
No 3B, review of statutory and mandatory requirements.
No 3C, review of maintenance procedures and documentation.
No 3D, instruction and training.

Materials and metallurgy

No 4A, materials and non-destructive testing.
No 4B, component design principles and practice.
No 4C, reliability assessment techniques.

The membership of the sub-committees and working groups totalled 88 persons and is shown in the Appendix.

The report

The first part of the report is divided into Part 1A and Part 1B. Part 1A contains the subjects and principles, with supporting statements, and recommendations made after consideration of available knowledge and experience. No attempt is made to suggest priorities for implementation of recommendations as this is a matter for mine owners. Part 1B contains what, at present, appear to be the best methods of applying these principles together with certain detailed supporting information and proposals. It is realised that new and improved methods will evolve, and new and improved materials become available, and that some of the detailed proposals may be superseded. Work continues on outstanding and additional subjects and these will be reported on in further parts to be published later.

Interim measures

The National Coal Board has set up a Co-ordinating Committee, with Mr R B Dunn Director-General of Mining as chairman, to study the implications of interim recommendations and take necessary action. This committee also deals on behalf of the National Coal Board with relevant issues in the Markham Official Report which have not been considered by the National Committee. Revision of the Coal and Other Mines (Shafts, Outlets, and Roads) Regulations 1960 is being undertaken by the Health and Safety Executive.

History of overwinds

The overwind at Markham Colliery on 30 July 1973 had more serious consequences than any other overwind in the United Kingdom since 1932 when 19 men at Bickershaw Colliery were overwound into a water filled sump and drowned. Following the latter accident a Departmental Committee enquired into precautions against overwinding. The main recommendations were embodied in legislation which prescribed standards of brake holding power and provision of automatic contrivances to limit the speed at which conveyances should pass the lowest entrance to shafts. This legislation has been followed by a continual
improvement in winding engine brake gear and protective equipment and is reflected in a decreasing general trend in the number of persons killed or seriously injured because of overwinds. Despite this trend, as illustrated in fig 2, the accidents at Brookhouse and Markham Collieries demonstrate that any one overwind can have very serious consequences. One aim of the National Committee is therefore to eliminate overwinds likely to result in injury.

The Markham Official Report: conclusions and recommendations

In the Markham Official Report, it is concluded that:

(1) The disaster was caused by the complete failure of the mechanical brake of the winding engine because the spring nest centre rod which was a single line component, broke. The design of the trunnion did not take account of the high pressure due to the spring nest, and the main lever could not rotate freely about the trunnion axle which had no practical means of lubrication. Consequently, operation of the brake produced bending forces and induced fluctuating stresses in the rod which it could not sustain. Cracks developed in the rod and one of them extended until failure occurred.

(2) The cracks which were present in the rod could have been detected before it broke by the magnetic particle method of non-destructive testing.

(3) There can be no criticism of the winding engineman who, as a last resort, attempted to stop the engine by pressing the emergency stop button provided for this purpose.

(4) It was always necessary to apply the mechanical brake to stop the engine but, had regenerative braking been available after the emergency stop button was pressed, there is little doubt that the speed of the cages at the end of the wind could have been significantly reduced.

(5) The fatal or serious injuries received by the men in the descending cage were caused by it crashing on to the wooden baulks at the bottom of the shaft. The
accident would not have been so serious, if instead of landing baulks, an arresting device had been installed below the lowest winding level.

Also in the Markham Official Report it is recommended that:

(1) All winding engines be examined and modified as necessary to ensure that the mechanical brakes should always be capable of bringing them safely to rest.

(2) Where possible the operation of winding systems should not rely on ‘single line’ components. If this cannot be achieved the systems should be modified to ensure that single line components are designed, operated and maintained to prevent danger.

(3) All winding engine brake components essential for safety be non-destructively tested as necessary and the tests should be repeated at appropriate intervals.

(4) A design analysis be made of all winding engine brake components essential for safety to ensure that the working stresses can be sustained and to establish definitive life. This analysis should take account of the fluctuations of stresses irrespective of the conventional static factors of safety. The use of screwed components should be avoided wherever possible.

(5) The control systems of electrical winding engines be reviewed with the object of making electrical braking available after the initiation of an emergency or automatic trip at least until the application of the mechanical brake has been proved.

(6) All solid landings in shafts be replaced by suitable arresting devices below the lowest winding level as soon as possible.

(7) An operating manual be prepared for each winding engine and the training and examination of winding enginemen be reviewed.

(8) Every winding engine which can attain a speed in excess of seven feet per second be provided with a rope speed indicator.

(9) The Coal and Other Mines (Shafts, Outlets and Roads) Regulations 1960 be revised to include additional statutory requirements for the safe winding of persons through shafts and unwalkable outlets.

1 Philosophy of braking

General principles

1 The principle which should be adopted for all winding engines is that the mechanical brakes shall be the ultimate means of retarding the winding system, and the objective to be pursued is that this principle should apply even in the event of the failure of one component. With electrically or steam powered winding machines, the power medium may be used for braking purposes, but as the power supply can be interrupted without warning this form of braking cannot be relied upon as the ultimate means of bringing the conveyances safely to rest.

2 Existing types of brake gear were examined and the possible modes of failure were assessed. It was concluded that the recommendations in the Markham Official Report were viable but that certain terms such as ‘safely to rest’ and ‘always’ should be stated in more specific form so that recommendations could be applied to design and practice.
**Mechanical brakes**

3 New mechanical brakes should be arranged and designed so that they contain no single line component the failure of which would prevent application of the brake either by the winding engineman or by a safety device. It is accepted that in the event of failure of a component there may be some loss of braking torque, but the design should be such that the brake still exerts a braking torque sufficient to bring the winding system safely to rest and produces not less than 50% of the normal braking force. Serious reduction of mechanical braking torque may also occur as a result of contamination of brake paths or linings by oil or moisture or other matter. It is not anticipated that in most cases the effect of such contamination would be greater than the effect of failure of a brake component and thus the effect of contamination would be within the 50% allowance for loss of braking force owing to failure of a component. In this context, to bring the winding system safely to rest means preventing the descending conveyance from passing the lowest landing at a speed greater than that which the pit bottom arresting devices can accept to bring the conveyance to rest at a specified rate (see paragraph 54); it also means ensuring that the ascending conveyance does not strike the headframe and that the detached capel is not wound into the winding engine house.

4 Existing mechanical brakes with single line components should be appraised to determine whether the brakes can be modified to eliminate these components and, where possible, they should be eliminated. If this cannot be readily achieved and fatigue design considerations show that single line components have not been designed and manufactured for infinite fatigue life, these components should be replaced within a defined period based on their fatigue life and their replacements should be designed and manufactured for an infinite fatigue life. Nevertheless, certain single line components (to be specified in the design guide referred to in Part 1B) although designed for infinite fatigue life should be given a definitive life. All single line components should be operated and maintained within their designed parameters, and should be subjected to regular non-destructive testing as specified in Part 1B at the intervals shown in table 1 in paragraph 116.

5 The retardation of a conveyance should not exceed 1g in order to minimise risk of injury to persons following application of the brake after an emergency trip. To achieve this in practical terms, the retardation of the rope at the drum should not exceed 16 ft/sec² (4.9 m/sec²) and should preferably be less than 12 ft/sec² (3.7 m/sec²).

6 Improved design standards, together with adequate standards of inspection, testing and maintenance should reduce the possibility of component failure, and the possibility of contamination of brake paths or linings. Work is proceeding on the selection and development of lining materials less susceptible to contamination.

**Electrical braking**

7 Where electrical braking is provided it is normally used as the service brake, and can also be designed to remain available after specific trip conditions as a back-up to the mechanical brake in the unlikely event of mechanical brake failure or severe brake lining and brake path contamination. Electrical braking should be retained at least until the mechanical brake is proved to be sufficiently effective to retard the winding system. Nevertheless, electrical torque and mechanical braking should not compound to produce either excessive or reduced rates of retardation. A statement on the significance of compounding of electrical torque and mechanical braking is in Part 1B.
DC winding engines

8 With most DC winding engines, the practice in the past has been to remove electrical power and apply the mechanical brake following an emergency trip. Power retained for electrical braking is also available for driving, and therefore it is necessary for the circuitry to be carefully designed and for electrical breaking after an emergency trip to be automatic in operation and beyond the control of the winding engineman. The principle proposed for the future is to retain electrical braking on DC winding engines following an emergency trip until the mechanical brake has been proved substantially effective by measurement of braking torque. Development of a transducer suitable for this purpose is proceeding.

AC winding engines

9 In the case of AC winding engines equipped with dynamic braking, that form of electrical braking can be readily retained under the control of the winding engineman following an emergency trip although the main supply to the winding engine motor will have been interrupted. In this respect the AC winding engine has an advantage over the DC winding engine in that the winding engineman can use the motor only for electrical braking and not for driving. In principle it is considered that AC winding engines which are not at present equipped with dynamic braking should be provided with dynamic braking. Furthermore a study has been made which shows that it is technically possible to apply dynamic braking automatically to AC winding engines utilising the principle of braking described above for DC winding engines. One trial has been carried out on an AC winding engine with dynamic braking and of a design particularly suited for this purpose, but further experience is necessary before firm general recommendations can be made.

Steam winding engines

10 In the case of both steam and compressed air winding engines the mechanical brake should be the ultimate means of retarding the system; the principles of operation of mechanical brakes for these winding engines need be no different from those for electrical winding engines. With most steam winding engines, reversal of steam may be used to replace or augment the mechanical brake during service braking and could be thus used to retard the winding engine in the event of mechanical brake failure. It is not practicable, however, to retain steam for automatic application of reverse power following an emergency trip in a manner similar to the retention of electrical braking on electric winding engines. Practice with steam winding engines is to cut off power in the event of an emergency trip by closing the throttle and disconnecting or ‘un-gabbing’ the throttle operating linkage. Special release valves exhaust the steam trapped between the throttle valves and cylinders and so limit its ability to do work.

2 Means of implementing philosophy of braking

Mechanical brake: design

11 In order to establish a design guide which will assist in the design of new winding engine mechanical brakes and enable existing brakes to be checked, a number of winding engines with differing types of mechanical brake have been examined physically (see figs 3, 4, 5 and 6). The levels of stress in their operating components were measured by strain gauging under conditions of normal and emergency braking, and under simulated conditions of severe maladjustment and excessively worn brake linings. On one winding engine additional tests were made to simulate the sudden loss of brake system fluid pressure which could be caused...
by the fracturing of a pipe: this allowed the back-up weight to fall at a greater rate than that resulting from an emergency trip and induce abnormally high transient stresses in the brake components. A summary of the tests is in Part 1B.

12 These results have been used to establish whether there are stress conditions shown by strain gauging which are not adequately covered by traditional methods of calculation. In addition, a study of stress concentrations and an appraisal of the configuration and geometry of these types of mechanical brake have been carried out.

13 It is concluded that:

(1) Generally, the normal operating stress levels observed during the tests were low so that even where stress concentrations occurred (such as in screwed portions) the range of stress was within the fatigue limit of the material.

(2) Primary steady state stresses in components ranging from brake off to brake on conditions, can be calculated sufficiently accurately by simple methods which were found to give reasonable agreement with the stresses measured.

(3) Secondary bending stresses can exist in rods owing to eccentricity, friction and self weight in addition to the primary stresses. The simple methods of calculation in common use do not allow for such secondary stresses and results showed that the addition of secondary bending stresses could double the primary stress level.

(4) There is ample evidence that fluctuating stresses whose magnitude is comparable with, and which are superimposed on, the primary steady state stresses, occur in some components when the brake is operated. Where they were observed during the tests, the magnitude of all stresses combined was low enough not to cause concern.

(5) Fatigue failure can occur in steel at stresses which are generally low particularly where there is a repeated range of stress and where there are points of stress concentration such as at screwed threads, welds, sudden changes of section and small manufacturing defects. As secondary bending and fluctuating stresses in addition to primary stresses can be expected to occur in mechanical brake components of winding engines, their effects on the fatigue life of components must be considered during design and manufacture. Details of these considerations are in the design guide referred to in Part 1B.

(6) High transient stresses many times greater than the primary stress changes in the normal brake operation can be caused in components when dead weights are allowed to drop. If the number of drops is large, the transient stresses can be greater than acceptable from the point of view of fatigue; but free fall of dead weights occurs only during tests or an emergency. Brake dead weights on winding engines operated by the National Coal Board are provided with cradles to ensure continued support for the weights should the support rod fail.

(7) Some general observations on geometry can be made. Although it is possible to design a satisfactory brake gear incorporating a multiplicity of rods, levers etc, adjustment to achieve satisfactory and balanced braking can be more difficult than with a simple design. Moreover, the possibility of introducing secondary stresses is greater. The calculations necessary for determination of secondary stresses are more complex than those required for primary steady state stresses, and can be performed more readily and reliably in the case of simple elegant designs of brake gear.
14 Recommendation: that the design of mechanical brakes for winding engines be based on the design guide referred to Part 1B.

**Mechanical brake: materials and construction**

15 Materials available for the construction of mechanical brakes, other than disc systems, have been investigated to determine those which are acceptable and to identify their specification. The procedures for fabrication and casting have also been examined.

16 Traditionally, tensile properties of materials have been the main consideration for design and mild steel was used generally but was not always to a recognised specification. Whilst consistent tensile properties can be achieved in mild steel, the overall suitability of a material for brake components is depending on a number of other properties which influence its resistance to fracture. The most important is notch ductility which is an indication of the resistance to brittle fracture in the presence of a defect. It is essential that mechanical brake critical components be made from materials with adequate guaranteed minimum notch impact values at temperatures likely to be encountered in service. Other important properties such as grain size, weldability, and graphite flake size in grey iron castings, have also to be considered.

17 A choice of suitable materials, identified by reference to British Standards, is in a table in Part 1B. As the aim should be to limit the types of steel used, a column giving a rationalised choice for a number of components is included.

18 All fabricated brake parts must be manufactured to a satisfactory standard to ensure reliability in service and methods of manufacture should be agreed before production commences. Quality control procedures are needed to make certain that recommended materials are used, that inspection is made at all stages of fabrication to maintain agreed standards of welding, and that final inspection includes non-destructive testing to confirm that manufactured components satisfy the requirements outlined in Part 1B.

19 For some components, notably brake paths and certain parts of brake engines, case materials are recommended, while for others there is a choice of materials so that parts may be either cast or fabricated. As all cast brake parts must also be manufactured to a satisfactory standard to ensure reliability in service, a foundry should be carefully selected on the basis of its standing and specialisation. In order that casting design is suitable for the application, there should be full liaison between the design engineer and the foundry. Again quality control procedures are needed during manufacture to ensure that material conforms to the specified chemical analysis and mechanical properties, and satisfies the non-destructive testing requirements outlined in Part 1B. Guidelines for fabrication and casting are in Part 1B.

20 Recommendations:

(1) The materials listed in the table in Part 1B be used in the construction of winding engine brake gear.

(2) Materials be identified by reference to British Standards. (Where this is not possible for some proprietary items, or because of new developments, the supplier should submit details of materials and their treatment to the customer for approval).

(3) The materials used be of such quality that components manufactured from them satisfy the non-destructive testing requirements outlined in Part 1B.
(4) Agreed quality control procedures be used during fabrication and casting.

(5) Tests and other criteria be specified in the contract.

(6) Test certificates and/or other forms of quality assurance be obtained.

**Mechanical brake: general requirements and essential features**

21 General requirements for new mechanical brakes for winding engines are in Part 1B. In preparing the guidelines, due account has been taken of design principles by modern braking equipment and existing specifications and practices, but freedom is left for individual designers to improve future products and take advantage of technological process. The aims are to:

(1) Ensure safety following failure or malfunction of any one component.

(2) Match brake performance to service and emergency requirements.

(3) Emphasise the need for the design and construction of the brake to be as simple as possible.

(4) Ensure that the brake will be applied following failure of fluid pressure in the system.

(5) Ensure that facilities are incorporated in the winding engine to enable routine statutory and maintenance tests to be carried out effectively.

(6) Ensure that load carrying components are designed and constructed for infinite fatigue life.

(7) Adopt the table of recommended materials.

(8) Ensure that the design includes facilities for adequate lubrication or eliminates the need for lubricants to be applied.

22 The essential features have been extracted from the guidelines for new mechanical brakes so that they can be applied to mechanical brakes on existing winding engines. These essential features are in Part 1B.

23 Recommendations:

(1) The general requirements in Part 1B for new mechanical brakes for winding engines be adopted.

(2) The essential features from the general requirements, as in Part 1B, be applied to mechanical brakes on existing winding engines.

**Electrical braking: retention**

24 On the majority of DC winding engines, electrical braking is automatically removed following an emergency trip although in a few cases it can be reinstated. On a minority of DC winding engines, electrical braking is retained and combined with mechanical braking to give a governed rate of retardation. On AC winding engines, where electrical dynamic braking is provided, it remains available following an emergency trip but it has to be applied by the winding engineman.
Figure 3 Diagrammatic arrangement of a deadweight applied fluid power released winding engine break (Pyehill No 2)

Figure 4 Diagrammatic arrangement of a spring applied high pressure hydraulically released winding engine break (Daw Mill No1)

25 Three present practices involving retention or reinstatement of electrical braking on DC winding engines were considered:

(1) Retention of electrical braking until the mechanical brake is applied, as installed on one new winding engine.

(2) The combination of electrical and mechanical braking systems to give governed rates of retardation.
(3) Automatic suppression of all electrical torque following tripping of the safety circuit with manual facilities to regain electrical braking.

Figure 5 Diagrammatic arrangement of a deadweight applied fluid power released winding engine brake (Barrow No2)

Figure 6 Diagrammatic arrangement of a spring applied hydraulically released winding engine unit brake (Langwith No1)

The advantages and disadvantages of all three practices are scheduled in Part 1B.

26 Practices (2) and (3) can only be applied to DC winding engines with a closed-loop system of control but practice (1) can be applied to DC winding engines in categories I, II and III of paragraph 27(1). Moreover it is considered that this is the only scheme that gives protection against circuit failure which might cause the motor to attempt to drive through the mechanical brake.

27 Control systems of both DC and AC winding engines were reviewed to determine the feasibility of making electrical braking available without the
intervention of the winding engineman after the initiation of an emergency or automatic trip, until the mechanical brake is proved substantially effective. The types of electric winding engine examined were divided into the following categories and numbers in use at mines operated by the National Coal Board are indicated in brackets.

1. DC winding engines:
   (i) closed-loop Ward Leonard system (76)
   (ii) closed-loop convertor supplied (76)
   (iii) open-loop with cam gear and oil servo assistance (8)
   (iv) open-loop with cam gear only (ie no oil servo assistance) (18)
   (v) open-loop without cam gear (10)

2. AC winding engines:
   (vi) closed-loop (24)
   (vii) open-loop with dynamic braking (205)
   (viii) open-loop without dynamic braking (182)

28. Examination of circuit diagrams established that with suitable circuit modifications all winding engines in categories I, II and VI can meet the requirement stated at the beginning of the previous paragraph.

29. Tests carried out on one winding engine in category III showed that it was feasible for that particular winding engine to meet the requirement but that the maximum landing speed was relatively high with electrical braking only, although this could be reduced by adjustment. To establish that the maximum landing speed of each installation in this category is acceptable when electrical braking alone is used, it is necessary to carry out similar tests. The test results are in Part 1B.

30. The winding engines in categories IV and V cannot meet the requirement without the provision of completely new control systems.

31. Several proposals for control schemes which could be applied to winding engines in category VII were examined and an electronic hydraulic control scheme was chosen. A schematic diagram and an outline description are in Part 1B. To prove the feasibility of the scheme, tests were carried out on a suitable winding engine and the results showed that the requirement could be met on this particular installation. It should be clearly understood that the majority of winding engines in this category would require substantial modifications to their control systems to achieve automatic application of dynamic braking.

32. Winding engines in category VIII have a variety of control equipment, details of which are in Part 1B. Reverse current braking is the only electrical means of retarding winding engines in this category and there is no reliable method whereby this form of braking can be applied automatically to meet the requirement. An improvement in safe working would be gained by adding dynamic braking to raise them to the standards of category VII. However, to determine if this is practical for each installation, it will be necessary to examine the significance of the power of the winding engine motor, the depth of shaft, speed through the shaft, and so on.
Winding engines in category VIII cannot satisfy the requirement without major modifications or, in many cases, replacement of their electrical parts.

33 Recommendations:

1. The objective be pursued for DC and AC winding engines that after the initiation of an emergency or automatic trip electrical braking is retained without the intervention of the winding engineman until the mechanical brake is proved substantially effective.

2. A torque control scheme for the automatic application of dynamic braking without the intervention of the winding engineman be further developed; and that one winding engine in category VII be fitted with such a scheme to gain experience prior to any firm recommendations being made about the future of winding engines in this category.

3. Electrical control schemes of DC winding engines in categories IV and V be brought up to the standards of those winding engines in categories I or II.

4. Consideration be given to uprating the electrical control scheme of DC winding engines in category III to the standards of those winding engines in categories I or II to take advantage of the improved control.

5. AC winding engines in category VIII be equipped with dynamic braking wherever practicable to bring them to the standards at least of category VII in which dynamic braking remains available for manual application by the winding engineman after an emergency or automatic trip.

**Braking torque: sensing transducer**

34 If electrical braking on winding engines is to be retained automatically following an emergency or automatic trip until the mechanical brake has been proved substantially effective, a reliable brake torque sensing transducer is required. Even though the mechanical brake is applied, indication of pressure between brake lining and path does not necessarily indicate that the anticipated braking torque is realised, because the remote possibility exists that contamination etc, could make the brake partially ineffective. A possible method of sensing this torque is to use a transducer which can discriminate between the stresses existing in the brake shoes or pivots when the brake is applied to a static drum, and those present when the brake is retarding a rotating drum.

35 Investigations have covered two possibilities. The first is based on the embodiment of a shear force transducer in replacement hinge pins for the brake shoes. The second is to use a bolt-on strain transducer which can be more widely applied; one particular type has shown considerable promise on test. Development work is also proceeding on an instrumentation and control system embodying standard modular units to be used in conjunction with the transducers.

**Automatic contrivances**

36 Winding engines with a winding speed which can exceed 12 ft/sec (3.7 m/sec) are required to be equipped with automatic contrivances which initiate application of the mechanical brakes, and may cut off power, to prevent the conveyances from:

1. reaching an excessive speed in the shaft;
(2) passing the lowest landing at a speed exceeding 5 ft/sec (1.6 m/sec) in the case of drum winding engines and 12 ft/sec (3.7 m/sec) in the case of friction winding engines; and

(3) travelling beyond a predetermined position above the highest landing.

37 It is concluded that automatic contrivances should be installed on all winding engines which have a normal maximum winding speed exceeding 5 ft/sec (1.6 m/sec). This is to reduce the possibility of any conveyance passing the lowest landing at a speed higher than the minimum contact speed specified in paragraph 54 for pit bottom buffers in drum winding installations. Nevertheless, safe operation of a winding engine cannot be realised unless the automatic contrivance fitted is reliable and accurate. Accordingly, the types of automatic contrivance listed in Part 1B were investigated and placed in the following categories based on experience:

A acceptable pending critical examination.

B to be phased out in due course.

C to be phased out as soon as practicable.

38 Because automatic contrivances in categories B and C were recommended to be taken out of service, they were excluded from the following critical examination. One of each type in category A was fully dismantled, examined on the bases of mechanical aspects of reliability, fail-safe and operational features. Calculations for factors of safety were carried out for the speed spending components. A minimum factor of safety of five was adopted, based on the ultimate strength of the material and the maximum operating load divided by the area of section. Where undesirable features or low factors of safety were found, manufacturers have been asked to make improvements; a schedule listing these actions is included in Part 1B. The electrical aspects of automatic contrivances in category A are being examined.

39 For those automatic contrivances which include provision for acceleration relief, manufacturers have been asked to produce designs for this feature so that it fails to safety.

40 The operation of an automatic contrivance depends on the integrity of its drive, but monitoring the drive shaft alone is considered insufficient. To detect failure, as many of the speed and distance elements in the automatic contrivance as is practicable should be monitored, either by integral devices or by a separate supervisory system. The question of separate drives to the automatic contrivance and depth indicator was examined. Provided the automatic contrivance is monitored, it is concluded that either combined or separate drives are acceptable because the depth indicator is monitored visually by the winding engineman. A scheme for monitoring the drive and a description of an electronic supervisory system are in Part 1B.

41 The manufacturers of each type of automatic contrivance have been asked to produce proposals for monitoring. Their schemes are to be compared with a separate electronic supervisory device, which is under development, so that the most effective method can be adopted. In addition, consideration should be given to monitoring other protective equipment associated with the function of the automatic contrivance (eg separately driven overwind devices, fast/slow braking devices, torque limit switches) which must function correctly to comply with statutory requirements.
42 Recommendations:

(1) An automatic contrivance be used on every winding engine that has a normal maximum winding speed greater than 5 ft/sec (1.6 m/sec).

(2) The use of simple overspeed devices, which trip at a single speed only, be limited to winding engines with a normal maximum winding speed not exceeding 5 ft/sec (1.6 m/sec).

(3) Automatic contrivances in categories B and C listed in Part 1B be replaced.

(4) Certain details of design of automatic contrivances in category A be improved as scheduled in Part 1B.

(5) Automatic contrivances of new or modified design be critically appraised before they are accepted for use.

(6) Automatic contrivances and protective equipment be monitored or a separate supervisor device be provided.

(7) Where a simple overspeed device is used on those winding engines that have a normal maximum winding speed not exceeding 5 ft/sec (1.6 m/sec), a second separately driven overspeed switch be used as an alternative to monitoring.

(8) The drive to any monitoring or supervisory device be separate from the drive to the equipment being monitored or supervised.

(9) The monitoring system or supervisory device cause the winding engine to be brought safely to rest in the event of failure of the drive to the protective equipment.

Safety circuits

43 Following detection of an abnormal condition by its associated equipment, such as the automatic contrivance, a safety circuit causes the winding engine to be brought to rest, prevents it from being moved, and in some cases indicates the nature of the abnormal condition.

44 Because of the importance of safety circuits, it is considered that they should not rely on single line components for functions essential to safety. Provision should also be made to give indication of any electrical fault which could render a safety circuit ineffective; alternatively, the winding engine should be brought to rest automatically if a critical fault occurs.

45 Examination was made of electrical engineering aspects of safety circuit design, operation and statutory requirements in relation to winding engines, lifts and associated activities at home and abroad. Winding engine practice in Great Britain provides a safety circuit which is independent of the normal means of control. It is considered that the principle of separation of safety circuits from the normal means of control is sound and recommendations for further improvements which follow are based on this principle. However the practice of a two part safety circuit, normally termed primary and secondary, does not provide an adequate division of trips for abnormal conditions on a basis of their importance in relation to safe manriding. Explanatory notes on safety circuits are in Part 1B.

46 It is therefore proposed that the abnormal conditions be classified in three categories as follows:
(1) CATEGORY 1 (those which would be dangerous to persons in a conveyance if not dealt with immediately).
These conditions would be detected by overspeed devices and overwind switches on the automatic contrivance, slack rope devices, any other safety device appropriate to this category, and headframe ultimate limit switches. It is convenient to subdivide category 1 as follows:

CATEGORY 1a abnormal conditions in category 1 other than those detected by headframe ultimate limit switches; and

CATEGORY 1b abnormal conditions detected by headframe ultimate limit switches.

The devices sensing abnormal conditions in category 1a should be in one part of the safety circuit which, through safety contactors, initiates application of the mechanical brake and may also remove power from the winding engine motor. Owing to the particular function of headframe ultimate limit switches, they should be in a second part of the safety circuit which, through safety contactors, initiates application of the mechanical brake and removes power from the winding engine by opening the main circuit breaker. Because of the nature of abnormal conditions in category 1 these two parts of the safety circuit, and other connected circuits, must be of high integrity which should be achieved by use of cable with screened cores (a specification of a suitable cable is in Part 1B) and earth fault protection together with at least two safety contactors suitably cross interlocked, in each part, to ensure that on operation of the protective devices the required action is always initiated.

(2) CATEGORY 2 (conditions which would not be immediately dangerous to persons in a conveyance but could be so if allowed to persist).
These conditions would include loss of excitation to a tachogenerator, sustained overloading main plant, and so forth. The protective devices should operate contacts in a third part of the safety circuit so as to open two safety contactors, suitably cross interlocked, which on being de-energised initiate application of the mechanical brake and remove the influence of the electrical drive. Means of removing the influence of the electrical drive depend on the type and nature of the winding engine control system. This third part of the safety circuit must be equipped with earth fault protection, and it is provided for these devices so that reliability of the two parts associated with category 1 may be enhanced by reducing the number of devices in those parts to a minimum.

(3) CATEGORY 3 (those which may be injurious to plant).
These abnormal conditions would include excessive temperatures in bearings and machine windings etc. The protective devices should operate contacts in a fourth part of the safety circuit which may be arranged to provide indication of the condition and/or inhibit further winding after completion of the wind. This part of the safety circuit must be equipped with earth fault protection.

Examples of typical devices which trip safety circuits under the three categories of abnormal condition are in Part 1B. A statement on protection of safety circuits against electrical faults with details of typical means of providing earth fault protection is also in Part 1B.

47 Recommendations:

(1) Abnormal conditions be classified in three categories as follows:

CATEGORY 1 dangerous to persons in a conveyance if not dealt with immediately;
(2) Each part of the safety circuit associated with categories 1 and 2 should have at least two contactors energised by the circuit and should not use single line components for essential functions.

(3) Each pair of contacts be monitored and cross interlocked so that failure of any one to function correctly is automatically indicated, and/or prevents the continuation of winding.

(4) Both parts of the safety circuit associated with category 1 be in conductors having individual conducting screens, all screens being earthed; and that these parts of the safety circuit be physically segregated one from the other and from any other circuit to avoid malfunction caused by leakage or induction.

(5) A reliable system of earth fault protection be provided for safety circuits.

(6) Ancillary circuits, indicator circuits, backing out circuits etc, connected to a safety circuit, be provided with the same protection against malfunction as the safety circuit.

(7) In those installations where winding of abnormal loads, eg long loads, conflicts with normal overwind protection, specific arrangements be made (as in paragraph 64) and formal procedures established for this to be done without risk of lowering the level of safety afforded by the normal overwind protection when man winding is resumed.

Rope speed indicators

48 Rope speed indicators are fitted to most winding engines to assist winding enginemen in controlling movement of conveyances in shafts in accordance with winding cycles. There is no difficulty in fitting this equipment and it is considered that provision of rope speed indicators should be extended to all winding engines.

49 Recommendations:

(1) Rope speed indicators to be fitted to all winding engines.

(2) For a winding engine with a bi-cylindro conical drum, calibration of the rope speed indicator be related to the largest diameter of the drum except where other practice is already established at the mine.

(3) The maximum permissible speed when men are travelling be displayed in the winding engine house.

(4) The maximum permissible speed when men are travelling, and the normal maximum winding speed, be marked on the scale of the rope speed indicator.

Maintenance, testing and training

50 Safe operation of winding engines depends upon implementation of effective planned maintenance schemes, testing programmes, and training of personnel. These should include lubrication standards and non-destructive testing procedures for components when new and when in service. Details of these requirements and recommendations are in section 4 of this report.
**Systems reliability**

51 It is considered that systems reliability analysis as applied in aircraft and atomic energy industries might have application to mine winding systems. An examination of the techniques employed was undertaken (see Part 1B). Such an analysis consists of the construction of logic diagrams of the winding engine, its operation, its components and their interdependence. For the reliability of the system and its parts to be quantified, it is necessary to have available, or to derive, failure data for components.

52 A pilot reliability analysis of a modern winding engine is being undertaken by an organisation experienced in such work. The contract includes a general assessment of the complete winding installation and a detailed assessment of the electrical safety circuit. The results of this study will be used to determine the feasibility and value of introducing a reliability assessment for winding installations in general.

**Pit bottom buffers**

53 In order to reduce the seriousness of the impact should a descending conveyance overwind when transporting men, it is recommended in the Markham Official Report that all solid landings in shafts be replaced by suitable arresting devices below the lowest winding level as soon as possible. Drum winding installations normally have beams across the bottom of the shaft which either carry timber baulks to register the cages during loading and unloading or are placed below the landing when kepys or tilting platforms are in use. Friction winding installations already have arresting devices in the pit bottom so consideration has been confined to the design and application of pit bottom buffers for drum winding installations.

54 Buffer design was developed on the understanding that the recommendations in this report on braking, automatic contrivances and single line components are applied. The buffers should be designed for drum winding installations on the basis that the maximum man load is descending and an empty conveyance ascending; and for an impact speed not less than 5 ft/sec (1.6 m/sec) or the speed resulting from an overspeed trip with the emergency mechanical brake force reduced by 50%, whichever is the greater. Pending further medical evidence it was also decided that lift practice buffer retardation design standards should be adopted. These are, for the same loading conditions, a maximum average rate of retardation of 1g and a peak rate of 2.5 g, ignoring transient peaks of less than 0.04 sec duration. These are minimum requirements; to cover other possible contingencies it is recommended that buffers be installed to cater for higher impact speeds whenever reasonably practicable.

55 Factors taken into account were that the buffers should:

- be anti-static; fire resistant and otherwise suitable for the pit bottom environment;
- preferably be self recovering and re-usable immediately following removal of a conveyance after an impact;
- be of a type which causes minimal rebound; not deteriorate significantly with age or repeated use;
- require minimal maintenance;
if possible, register the position of a conveyance during mineral and materials loading so that keps and beams are not required for this purpose; and be of a type which can fit into existing installations as far as possible.

56 Designs for arresting devices submitted by manufacturers and members of the public were examined; and the above factors led to the manufacture of prototype buffers for test based on a resilient type developed for the motor industry rather than on hydraulic cylinders. These prototypes have flexible members made of rubber reinforced with terylene and nylon fibres. They are intended for disposition in pit bottoms under conveyances in sufficient numbers to meet the requirements in paragraph 54. Each buffer may be subdivided as illustrated in fig 7 or built up of individual units.

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This is a web-friendly version of Safe manriding in mines: First Report of the National Committee for Safety of Manriding in shafts and Unwalkable Outlets, originally produced by HM Inspectorate of Mines.

Figure 7 Arrangement and detail of pit bottom buffers and cage
57 Tests of the prototype buffers were made in a mine shaft when a cage weighted with known loads and fitted with retardation transducers was run into them at varying speeds (see fig 8). Results have been analysed to develop design criteria for improved characteristics and to obtain a better appreciation of the dynamic effects. The various test results which are summarised in Part 1B are sufficiently encouraging to justify further development.

Figure 8 Prototype pit bottom buffers

58 In many existing installations it may be possible to mount the buffers on the steel pit bottom beams in place of the timber baulks. However, it is possible that the buffers will not be capable of providing a sufficiently accurate register of the conveyances for mineral and materials loading. Where keps are retained or platforms used for this purpose, they would need to be proved clear of the conveyances before man winding commences (see paragraph 72).

59 Conclusion:
It is possible to use energy absorbing devices which will minimise injury to persons in the event of an overwind.

60 Recommendation:
That development work be continued, so that buffers of suitable design are available for installing in pit bottoms of all drum winding installations.

3 Headframe and shaft equipment

61 To enable the philosophy of braking to be implemented by the means described in section 2, it is necessary to establish matching standard for certain items of headframe and shaft equipment. Standards and modes of working have
been investigated, conclusions reached and recommendations made. It is not intended that future introduction of improved technology should be inhibited by these recommendations.

**Headframe ultimate limit switches**

62 For final positive detection of an overwound conveyance, ultimate limit switches are required in the headframe. These should, when operated, initiate cutting off all power form the winding engine and application of the mechanical brake.

63 Direct mechanically operated heavy duty switches are preferred since they have been found more reliable in practice than magnetic proximity or photo-electric types. Moreover, they should be designed and sited so that their contacts are driven positively to the open position and the switches are not damaged by passage of conveyances in either direction. The switches should be protected against weather, and be provided with safe access for maintenance.

64 For testing purposes, backing out after an overwind, and handling long materials in some cases, a self-return lockable switch should be provided to enable a conveyance to be moved after an ultimate limit switch has been operated. This self-return lockable switch should be operated only by an authorised person and be located so that he can observe movement of the conveyance. The desirable position for this switch is at the surface landing and only authorised persons should be in possession of a key. The operative state of this switch should be indicated to the winding engineman. A typical circuit diagram is shown in Part 1B.

65 Recommendations:

1. **Headframe ultimate limit switches**, operated directly by a conveyance, designed to initiate cutting off all power from the winding engine and initiate application of the mechanical brake, be provided for all winding installations.

2. Headframe ultimate limit switches are of the mechanically operated heavy duty type, protected against weather, capable of withstanding normal operating impacts imparted by conveyances, and have contacts driven positively to the open position; or be equally effective alternative devices.

3. Safe access to the headframe ultimate limit switches be provided for maintenance.

4. A self-return lockable type switch be provided to enable a conveyance to be moved under observation after a headframe ultimate limit switch has been operated.

5. A key for this self-return lockable type switch be available only to persons authorised to supervise conveyance movement after a headframe ultimate limit switch has been operated by a conveyance.

6. The operative state of this self-return lockable type switch be indicated to the winding engineman.

**Overwind catches in the headframe**

66 When the severity of overwind of a drum winding installation is such that a detaching hook operates, the conveyance continues upward until its kinetic energy is dissipated. This upward movement results in slack suspension gear which can be severely stressed and possibly broken if the conveyance is allowed to fall back.
through an excessive distance. Because of the danger which can develop from this condition, consideration was given to the provision of catches in all headframes to limit the distance a detached conveyance can fall back.

67 In Great Britain, the majority of modern drum winding installations and all friction winding installations have catches in the headframes to limit fall back of overwound conveyances. In friction winding installations, detaching hooks are not used but terminal bumping beams are positioned over retarding devices in headframes and towers. Since a severe overwind may result in breakage of ropes or suspension gear at terminal bumping beams, catches are essential and required by legislation. A note on technical aspects is in Part 1B.

68 Recommendation:

That catches or equivalent devices be provided in the headframe of every drum winding installation to prevent conveyances from falling back an excessive distance after detachment.

**Keps and other shaft side equipment**

69 In Great Britain, regulations require that keps shall be used when persons are entering or leaving a cage at a place at which they are provided. However, if keps are not provided at the highest landing, then special regulations are required to be applied to ensure that a conveyance does not move as men are entering or leaving the conveyance. This is normally achieved by interlocking shaft side gates with the winding engine brake as described in paragraph 83.

70 To ensure unrestricted passage of conveyances in shafts the possibility of elimination or safer use of shaft side equipment was examined. Keps are included in this category, and in many winding installations they are used to register the position of cages at the highest landings during mineral winding. They may also be used for this purpose at the lowest entrance to shafts.

71 Keps at the highest landing in a shaft would be a possible source of danger should they inadvertently obstruct cage movement and cause slack rope (see paragraph 74) and keps at the lowest entrance to a shaft could inadvertently interfere with the descent of an overwound cage into any buffers set below them.

72 Where shafts are used for winding mineral or materials as well as men, and keps are installed, to ensure keps cannot obstruct the passage of cages when men are wound, it is necessary to interlock them with the winding engine to prevent cage movement unless keps are proved clear. Some shaft side equipment, other than keps, could also prevent free passage of conveyances so it too should be interlocked; this is described under brake locking in paragraph 83. Where keps are provided, a change in statutory regulations may be needed if keps are not to be used when men are wound. An interlocking arrangement is described in Part 1B.

73 Recommendations:

(1) Where keps are installed they are not used when men are wound and that legislation be examined accordingly.

(2) Adequate interlocking is provided where keps need to be retained for purposes other than man winding, to ensure the keps cannot obstruct the passage of cages when men are wound.
(3) Adequate interlocking be provided so that shaft side equipment cannot be operated incorrectly to cause an obstruction which can prevent passage of a conveyance in the shaft.

**Slack rope protection**

74 Slack rope is created when the winding engine is in motion and the descending conveyance is restrained at the top of the shaft or at any point within the shaft. Under these conditions there is a danger that the conveyance could fall freely and rapidly take up slack rope. It is therefore considered necessary to have a system or device to detect immediately either that the condition for creation of slack rope exists or that slack rope has already been generated.

75 The majority of existing devices detect slack rope by means of bars or stretched wires across the rope holes of the winding engine house. In some installations, the device has to be made less responsive to accommodation rope oscillations during normal winding. Moreover, owing to the balance of the rope, the system is only effective when a conveyance is in the vicinity of the shaft top.

76 Electronic devices have been developed which compare movement of the conveyance in the vicinity of the surface with movement of the winding engine drum. When the difference in movements reaches a pre-determined value, an error signal from the device can either trip the safety circuit of the winding engine or give an audible and visual warning but this system also is not effective throughout the shaft. Neither this system nor that described in the previous paragraph is considered ideal.

77 A third method in use at two collieries is based on detection of slackening of conveyance suspension gear: excessive movement causes a signal to be transmitted inductively to the surface via the winding rope. Disadvantages are that it may not be practicable where suspension gear slackens normally during winding and that slack rope may not always be detected when a conveyance is in the vicinity of the shaft top, owing to balance of the rope. However, the method is designed to be effective throughout the remainder of the shaft.

78 Some existing protective devices are connected only to give audible and visual warning; but when these devices are thoroughly reliable they should be connected into the safety circuit to cause the winding engine to be brought to rest automatically, as well as give an alarm and indicate to the winding engineman that they have operated. Moreover, they should be of fail-safe design and sited to operate on generation of the minimum amount of slack rope commensurate with operating conditions.

79 To be able to retrieve slack rope after the winding engine safety circuit has been tripped, it is necessary to incorporate a switch in the safety circuit to enable the safety contactors to be reset. There are two procedures for retrieving slack rope:

1. To allow the winding engineman to take immediate action to retrieve slack rope. In this case the reset switch should be of the self-return pattern and preferably connected to prevent further generation of slack rope.

1. Not to allow the winding engineman to take immediate action on the premise that the speed of operation of the device is sufficient to prevent formation of an excessive amount of slack rope. In this case the reset switch should include a latched key and would be operated only by a nominated person.
80 Procedure (1) is preferred to minimise the time men may be held in a shaft. However, the system should include a locking latched type slack rope switch which can only be reset by means of a key so that slack rope can be retrieved immediately but normal winding is prevented until the situation has been assessed by a nominated person.

81 As incidents have occurred because of conveyance obstruction at points throughout the lengths of shaft, there is need for a reliable method of slack rope protection which will operate with a conveyance at any position. A full list of requirements for such a device is in Part 1B and a programme of development is being carried out. Comprehensive conveyance position monitoring is referred to in paragraph 95.

82 Recommendations:

(1) Development is pursued of a fail-safe system of slack rope protection which compares movements of the conveyance with that of the drum or sheave throughout the wind.

(2) Reliable slack rope protection be provided at surface decking zones at all shafts where drum winding engines are used; and that it be arranged to bring the winding engines to rest when operated.

(3) Audible and visual alarm be given to the winding engineman when slack rope protection operates.

(4) Indication is given of the direction of travel required to retrieve slack rope; alternatively, that slack rope protection be connected in the winding engine safety circuit in such a manner that it can be incorporated in a backing out circuit.

(5) Until a fail-safe system of slack rope protection is developed arrangements ensure that a winding engineman can immediately retrieve slack rope, subject to prevention of normal winding until the situation has been assessed by a nominated person.

Brake locking

83 In winding systems where keps are not used when men are wound it is a practice to have on the winding engine brake lever a locking device associated with shaft gates at all landings, and arranged to prevent initiation of conveyance movement when a shaft gate is open. As referred to in paragraph 72, it is considered that winding safety would be enhanced by applying the brake lock principle to other shaft equipment which could prevent free movement of conveyances. The principle could also be applied to shaft signals.

84 Recommendations:

(1) All winding engines used for the transport of persons be fitted with an automatic device capable of locking the winding engine brake lever or brake gearing position with the mechanical brake fully applied.

(2) The brake locking device be interlocked with associated apparatus to ensure that, during normal manriding, when the conveyance is stationary, and the brake fully applied, the brake can be released only when:

   all shaft gates or barriers are fully closed;
all keps are proved clear;
all landing platforms and other inset equipment are proved in a safe position;
and
any emergency stop device has been reset after an emergency stop signal.

(3) During normal man winding a visual and audible warning be given to the winding engineman if, when the brake is not fully applied, any shaft gate is moved from the closed position, any keps are not proved clear, or any platforms or inset equipment are not proved in a safe position.

(4) Visual indicators be installed at each normal man winding level in a shaft to show when the winding engine brake is in the on position and locked in that position.

(5) A manually operated switch be provided at each normal man winding level to activate the brake locking device so that, when the winding engine brake is applied, it is locked in the on position and men may work safely in, on, or around a stationary conveyance, and that this switch be of a captive key operated type from which the key can be removed only when the switch is in the brake locked position.

Shaft signals

85 To establish the principals to be applied, the main advantages and disadvantages of existing shaft signalling systems were examined together with the British statutory code of signalling. This work is continuing.

86 The majority of installations employ electrical relays with manually initiated signals transmitted by individual pulses which are received visually and audibly. A few comprise a push button operated relay system in which each button is numbered so that, when it is pressed, a signal corresponding to the number is transmitted to provide audible and visual indication. These are of a more modern type and do not require the operator to transmit individual pulses which can give rise to incorrect signalling owing to variations in the rate of initiating pulses. A small number are of the clock dial type and employ an electro-mechanical device to operate a pointer on a dial for visual indication of the signal. These do not fulfil the destination hold requirement and are obsolescent. All existing signalling systems do not fail-safe in the event of short circuit or earth fault.

87 The desirability of amending the British statutory code of signals to remove the dual rope of the signal one for raise when stopped, or stop when in motion, was considered. It was decided that a change in this well established practice could cause mistakes and the difficulties would be alleviated by the interlocking of shaft gates with the winding engine brake as referred to in paragraph 83.

88 Safety would be enhanced by indicating to a winding engineman when a signal received by him is either false or incomplete. False signals are those which are not initiated by either the banksman’s or the on-setter’s signalling apparatus and incomplete signals are those received by the winding engineman from either the banksman or the onsetter but not from both. Incomplete signals will be given when the first person is lowered to a level in the shaft where there is no on-setter, so special provision would be needed to defeat the incomplete signal indication and the first signal sent from such a landing should cancel this defeat arrangement automatically. A means of providing indication to a winding engineman that a signal received by him is either false or incomplete is in Part 1B.

89 Existing emergency stop facilities are considered to require additional features. Once an emergency stop signal has been transmitted, it should not be possible to
cancel it by subsequent action signals and this could be achieved by the use of latched type stop buttons. Where possible an emergency stop signal should activate the winding engine brake locking device.

90 Recommendations:

(1) The existing British statutory code of signals be retained.

(2) Existing clock dial signalling systems be replaced.

(3) Shaft signalling systems be provided with visual indication of ‘stop – false signal’ to cater for the receipt of a signal by the winding engineman which has not been initiated by operation of either the banksman’s or an onsetter’s signalling apparatus.

(4) Provision be made on all shaft signalling systems for the visual indication of ‘stop – signal incomplete’ to cater for the receipt of a signal by the winding engineman from either banksman or onsetter but not from both.

(5) Equipment be provided at all entrances to a shaft, except the surface man winding level, so that a signal can be safely transmitted from inside a conveyance.

(6) Provision be made to enable shaftsman to transmit signals efficiently from a conveyance to the surface from all positions in a shaft; and that either radio, inductive loop systems or other no less effective system be used where other methods are inadequate.

(7) Where assistant banksman or assistant onsetters are employed, a locked key system of switches and signalling keys, or an equivalent method, be used to provide the banksman or onsetter with control of the number of assistant signalling stations in use; and that such systems be interlocked to prevent the transmission of an action signal by onsetter or banksman until the assistants employed have signalled ready.

(8) Emergency stop facilities be provided with all shaft signalling systems and that it be possible to cancel an emergency stop signal only at the position where it is initiated and only by means other than an action signal.

(9) Shaft side equipment be electrically interlocked in such a manner as not to interrupt the transmission of shaft signals.

Shaft communications

91 The mine telephone exchange may prove to be inadequate because of overloading in the event of an emergency in a shaft. Accordingly, existing systems of voice communication between onsetters, banksmen and winding enginemen were examined, together with systems of communication with persons in conveyances and with shaftsmen. It is concluded that it is preferable to provide a separate loud speaking telephone system which would not be affected by any loading of the mine telephone exchange, for communications between the winding engineman, banksman and the onsetters at pit bottom and any other entrances to the shaft.

92 Speech communication with persons in a conveyance is desirable, particularly in the event of an incident, manoeuvring in the shaft, and when men are wound to or from a shaft entrance where there is no onsetter. It is also desirable that speech
communication be available to shaftsmen who may be on top of a conveyance but shaftsmen are still required to transmit statutory signals.

93 Communication for the purposes referred to in the last paragraph could make use of radio or inductive links, which are suitable for voice communication and the transmission of statutory signals. Shaftsmen’s voice communication and signalling systems should be designed so far as is practicable to avoid common mode failure.

94 Recommendations:

(1) A separate loud speaking telephone system be installed to provide communication facilities between a winding engineman, banksman, and onsetters at pit bottom and any other shaft entrances.

(2) Shaftsmen be provided with means of speech communication with the banksman and winding engineman.

(3) Shaftsmen’s signalling and speech communication systems be designed so far as is practicable to avoid common mode failure.

(4) Speech apparatus be installed to enable persons on each deck of a cage to communicate with the banksman and winding engineman.

(5) Attention be given to the development of power supply units which can be housed satisfactorily on conveyances and which are capable of supplying all the communication, signalling and electrical protective systems on conveyances without the need for battery replacement more frequently than once per week.

Cage position monitoring

95 Knowledge of the precise position of a conveyance in a shift is fundamental to safe control and such information is usually obtained from the rotation of the winding engine drum or sheave. This arrangement suffers from the disadvantages that it does not take into account discrepancies between movement of the conveyance and the drum or sheave which may arise if a descending conveyance is obstructed, or if ropes driven by friction are displayed by creep or slip. A comparison of movement of a conveyance with that of the drum or sheave is required to detect this type of malfunction.

96 A system is available which detects a conveyance in a shaft by an inductive loop disposed around the shaft but comparison of movement is made only at that point. Development of this system in Great Britain is at the practical trials stage.

97 The following methods have been examine for continuously monitoring the position of a moving conveyance:

(1) High frequency radar and ultrasonic ranging: these have the disadvantage of a comparatively widely angled beam which is reflected by obstructions in the shaft and prevents reliable monitoring of conveyance position.

(2) Laser ranging: this overcomes objections arising from the width of the beam but requires the conveyance to have a clean reflecting surface which is difficult to maintain.

(3) Proximity switch devices: as these are limited to fixed locations in the shaft, they provide indication of the position of the conveyance only at those points.
4 Maintenance testing and training

Maintenance

100 A detailed re-appraisal of schemes of maintenance for winding equipment has been carried out which included an examination of the effectiveness of basic maintenance and associated administrative procedures and documentation. It was not possible to consider maintenance arrangements for all types of winding engine because of their large variety. It was therefore decided to conduct a pilot exercise on three general types, to appraise maintenance procedures and methods in use. This pilot exercise was carried out on a cross compound steam driven drum winding engine, an AC geared clutched drum winding engine, and a tower mounted converter supplied DC direct drive friction winding engine. A model code was prepared to appraise winding engines in terms of their mechanical and electrical components, a re-appraisal of existing maintenance check lists, and preparation of a detailed scheme of maintenance for each of the three winding engines.

101 The Coal and Other Mines (Mechanics and Electricians) Regulations 1965 require each mine manager to have at all times in force a scheme in respect of all mechanical and electrical apparatus providing for systematic examination and
testing of the apparatus to ensure proper maintenance. In each scheme, at mines operated by the National Coal Board, the frequency of routine maintenance is detailed in the form of work lists and the nature of examinations to be carried out on each item of equipment is specified in associated check lists. For the purpose of the exercise, the use of these documents was accepted in principle.

102 As part of the pilot exercise maintenance information manuals have been prepared and it is concluded that such a manual should be prepared for each winding engine with information presented in four sections as follows:

(1) WINDING ENGINE SPECIFICATION. This should contain operational and technical particulars, and lists of mechanical and electrical equipment.

(2) WINDING ENGINE OPERATION, CONTROL AND SAFETY SYSTEM. Controls and instruments used by the winding engineman should be described together with control and safety systems.

(3) PERFORMANCE MAINTENANCE. Examination and testing requirements should be specified to ensure continuance of the required performance of safety and control systems.

(4) EQUIPMENT MAINTENANCE. Examination and testing requirements should be specified for each item of electrical and mechanical apparatus.

103 Some important aspects of maintenance which were considered are given below, together with relevant observations:

(1) Whether inspections, examinations and tests required by the existing maintenance check lists are appropriate and complete. Existing check lists for winding engines are often of a general nature (eg steam winding engine, electric winding engine) and should be used for guidance only. Winding engines are individually designed, and each requires its own check lists, but where standardised equipment forms part of an installation then common check lists for such equipment may be used.

(2) Whether sufficient detailed information is available for adequate maintenance. Technical documentation for detailed maintenance of winding engines is usually inadequate and of too general a nature, but good detailed information is available for some items of equipment (eg switchgear and high pressure hydraulic equipment).

(3) Whether specialised training is necessary for maintenance supervisors and craftsmen. Winding engine maintenance is generally carried out by selected persons and familiarisation and specialised training takes place ‘on the job’. This arrangement has been generally satisfactory, but there is a possibility that available experience and expertise will not be effectively passed on. Formal specialised training should therefore be given to winding engine maintenance men.

(4) Whether additional examination by specialists are necessary. Routine examination and maintenance of winding engines, including automatic contrivances and other parts which are particularly vital to safety, is the responsibility of the mine mechanical and electrical engineering staffs. Where special tests or equipment are required, the work must be carried out by persons having the particular skills necessary. An additional safeguard would be provided by a system of ‘over inspection’ carried out by persons other than members of the mine engineering staffs.
104 Recommendations:

(1) Check lists for winding engines detail the examinations, tests and maintenance specific to individual winding engines.

(2) A standard procedure be adopted for reviewing winding engine maintenance schemes and that this procedure is applied to every installation. A suitable procedure is described in Part 1B.

(3) Formal specialised training, including practical instruction, be given to persons responsible for winding engine maintenance; and that the training cover examination, testing and maintenance requirements of automatic contrivances, mechanical brake gear and all control equipment.

(4) A system of over inspection be established as part of the manager's scheme for the mine for all winding engines whereby competent persons other than mine engineering staffs carry out or supervise a thorough examination of the winding engine at intervals not exceeding three years.

(5) A maintenance information manual be prepared for each winding engine containing information in four sections containing:

winding engine specification;

winding engine operation, control and safety systems;

performance maintenance; and

equipment maintenance.

Maintenance procedures and documentation

105 Existing administrative procedures and associated documentation, common to many manager’s schemes of maintenance within the National Coal Board, were studied to see if they could be improved. These procedures and documents, which are also used for other equipment in addition to winding engines were considered to be sound in principle, but detailed modifications are proposed to increase their flexibility in order to raise the standard of reporting and simplify the task of scrutinising the reports. New style headings have been designed to remind persons who use the forms of the legal requirements of the manager’s scheme. One of the proposed new forms is for reporting against non-routine specific tasks such as installation of equipment and examinations following incidents, which often affect plant histories.

106 A description of general requirements of the scheme and a schedule of engineering administrative procedures, documentation, duties and responsibilities of personnel are in Part 1B. The documents proposed are as follows:

(1) Schedule: this lists items of plant by type, together with frequency of maintenance tasks, and reference numbers of maintenance check lists which prescribe the nature of these tasks. A second sheet is for use by the manager to give interim authorisation for amendments to this schedule.

(2) Plant specification.

(3) Plant history.
(4) Work instruction and report: there are three different forms for use; one is issued each week to each person detailed to carry out routine daily and weekly maintenance tasks; another is issued weekly but used for tasks at intervals longer than one week; a third is used for non-routine tasks.

(5) Shift report: a person carrying out daily and weekly maintenance tasks reports defects on this form; periodic (that is, where the intervals are longer than one week) and non-routine reports are made on the work instruction and report form.

(6) Defect action sheet: this form is issued to initiate action to rectify a defect which has been reported; and has provision for reporting on action taken by the person rectifying the defect.

(7) Application for temporary amendment to the manager’s scheme; this form is used to notify an engineer of the mine of all maintenance tasks entering the final week of the tolerance for their completion; provision is made for the manager to authorise temporary amendment of the scheme.

107 Recommendation

That each manager’s scheme for the mine incorporates the principles embodied in the procedures and documentation in Part 1B. Although these procedures and documents are related to activities of the National Coal Board the principles involved are considered applicable to winding engines in general.

Lubrication of winding engine brake gear

108 The general principles of lubrication are well known but lubrication of parts of winding engine mechanical brake gear requires special consideration as small angular movements and high bearing pressures are frequently inherent in the design. Pivot bearings which may have to operate several times in each wind often have those characteristics. Pivot bearings are difficult to lubricate effectively because oscillating motion tends to move lubricant away from the loaded zones. With continuous rotation, however slow, distribution of lubricant in a bearing is much better. Inadequate lubrication results in increased friction which can lead to wear, fretting, or lost motion, any of which may limit free angular movement so that bending stresses are repeatedly introduced in rods.

109 The accident at Markham Colliery was caused by failure of inset bearing pads to roll freely on a trunnion axle, so that a rod connected to the trunnion axle was subjected to severe bending stresses in addition to its normal designed tensile stress during every brake application (fig 1). The rod failed from fatigue after 21 years service. There had been no provision for introduction of lubricant to the loaded surfaces of the trunnion bearings and both axle and bearing pads were made of similar soft steels. Since angular movements in brake gear are usually small, lack of free movement is difficult to detect even with the most thorough maintenance examination until deterioration of bearings or fatigue cracks in rods begin to appear. Therefore, correct initial design with suitable materials and adequate provision for lubrication is most important.

110 On existing winding engine brake gear, where impregnated or anti-friction bushes are not used to provide lubrication to loaded zones of pivot bearings, alternative facilities for adequate lubrication must be provided. Where grease is used, centralised lubrication systems have the advantage that grease may be applied to points where access is difficult. Nevertheless, it is necessary for sufficient central dispensing stations to be suitably located so that a point being lubricated may be
readily inspected to prevent over lubrication which may result in contamination of brake paths. Individual dispensing points at a central station are preferred as a blocked lubrication point fed from a common dispenser can remain undetected.

111 Recommendations:

(1) Schemes of maintenance include criteria for examination of all pivot bearings in winding engine brake gear, particularly bearing surfaces, for excessive wear, distortion, fretting, or lack of adequate lubrication.

(2) Schemes of maintenance include non-destructive testing examination of rods adjacent to pivot bearings at frequencies and with procedures as described in the next subsection and detailed in Part 1B of this report.

(3) Schemes of maintenance specify remedial action to be taken.

(4) Bearings in existing winding engine brake gear be reviewed in comparison with the design guide referred to in Part 1B.

**Non-destructive testing of winding engines**

112 Non-destructive testing is necessary as one of the means of ensuring the quality of some winding engine components prior to service, and subsequently in course of routine testing to detect the onset of any defect. Existing practices for this type of testing of winding engine components were examined and it was concluded that the methods and frequency of testing in use for drum shafts, intermediate shafts, main reduction gears crank pins and crosshead pins do not require urgent modification but that they should be reviewed in relation to future developments. At this stage it seems that non-destructive testing of winding engine drums by magnetic particle inspection methods at intervals of not more than 10 years is sufficient. These intervals can be reduced if necessary, but investigation of this subject and the application of non-destructive testing to other items is proceeding. Details of test methods are in Part 1B.

113 For non-destructive testing of winding engine mechanical brake parts, suitable procedures involving magnetic inspection supplemented by ultrasonic testing and dye-penetrant methods have been developed. During service it is possible for excessive wear and corrosion to occur and, in order to monitor these, provision has been made in the procedures for visual examination and for measurement of wear. The limits of wear should be defined at the time of design. Details of procedures are in Part 1B.

114 As part of the procedures to assist in ensuring freedom from failure it is necessary to determine the intervals between examinations, and these will be influenced by a number of factors, namely: the duty of the installation; the stressing of a particular components; the significance of failure; and the size of acceptable imperfections. From a consideration of the significance of failure it is possible to identify in a braking system critical components which may be defined as any component, the failure of which will result in the loss of at least 50% of braking area or force. For the purposes of non-destructive testing three classifications of components are made, namely:

(A) single line components;

(B) other mechanical brake critical components the failure of which will result in the loss of at least 50% of braking area or force;
(C) non-critical components the failure of which will result in the loss of less than 50% of braking area or force.

However, where historical evidence in respect of failure or design indicates a component classified under (B) may be subjected to the requirements of classification (A).

115 From experience gained from examination of brake gear in service it is considered that the interval between examinations can be determined from the probable number of applications of a winding engine brake. This is approximately proportional to the number of winds, but with components in classification (A) the maximum interval should be five years.

116 Intervals between examinations can therefore be determined from the number of winds per year. This number varies widely, and it is proposed that the duties of installations be divided into three groups: heavy, medium and light. The groups proposed are:

- HEAVY DUTY, more than 200,000 winds per year;
- MEDIUM DUTY, 10,000 to 200,000 winds per year; and
- LIGHT DUTY, less than 10,000 winds per year.

A wind is defined as a single journey in a shaft. Table 1 shows the proposals for frequency of examination of mechanical brake gear.

Table 1 – Frequency of non-destructive testing of winding engine brake gear

<table>
<thead>
<tr>
<th>Duty of installation</th>
<th>Critical components</th>
<th>Non-critical components</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Classification (A)</td>
<td>Classification (B)</td>
</tr>
<tr>
<td>Heavy</td>
<td>1</td>
<td>2 to 3</td>
</tr>
<tr>
<td>Medium</td>
<td>2</td>
<td>3 to 5</td>
</tr>
<tr>
<td>Light</td>
<td>3 to 5</td>
<td>7 to 10</td>
</tr>
</tbody>
</table>

117 The non-critical components in classification (C) require less frequent examination, but it is considered that a visual examination of these components should be made at the time when full non-destructive tests are made on components in classification (B).

118 Recommendations:

1. Routine non-destructive testing of winding engine, drums, drum shafts, intermediate shafts, main drive reduction gears, crankpins, crosshead pins, automatic contrivance drives and depth indicator drives is conducted in accordance with procedures set out in Part 1B.

2. The results of non-destructive testing of winding engine brake parts are assessed in accordance with the procedure in Part 1B; and necessary action taken in accordance with that procedure.
(3) Intervals between non-destructive tests of winding engine brake components are those proposed in table 1 but these may be subject to modification after further experience.

(4) Any component, failure of which would result in loss of less than 50% of effective braking area or mechanical brake force, be visually examined during each non-destructive test of components in classification (B).

(5) Reference is made to the appropriate manufacturer concerning wear limits of non-destructively tested components of a winding engine or, where this is not possible, to some other competent person nominated by the owner of the mine.

(6) Consideration be given to providing spares for those critical components which require frequent non-destructive testing, so that the winding engines concerned are not out of service for prolonged periods.

Testing of winding engines

119 To comply with regulations in Great Britain, it is necessary to carry out a series of tests when a winding engine which is ordinarily to be used for winding persons is first installed, and thereafter at periods not exceeding three months for drum winding engines and six months for friction winding engines.

120 Differing intervals between tests have been considered. Category A automatic contrivances are unlikely to go out of adjustment, and it is recommended (paragraph 42 (3)) that category B and C automatic contrivances be withdrawn. It is further recommended (paragraph 42 (6)) that automatic contrivances and protective equipment be either monitored or supervised by a separate device. Therefore it is considered possible to establish the interval between statutory tests at six months for all types of winding engine. However, where it is known that controls of a steam winding engine require frequent adjustment, the interval between statutory tests for such an engine should remain at three months.

121 For all types of winding engines, the statutory overwind tests carried out at weekly intervals and the brake holding tests should continue. Consideration should also be given to making the latter test on a shift basis to ensure that contamination has not reduced brake effectiveness.

122 A testing code for drum winding engines has been used and continually developed by the National Coal Board over a number of years, and a re-appraised model code based on this original is in Part 1B. A model testing code for friction winding engines, based on that for drum winding engines and suitability modified to take account of special regulations, is being prepared and will be included in Part 2 of this report. The codes, which incorporate statutory tests, are designed to check that the brake, automatic contrivance and associated equipment are properly adjusted and include tests of holding power of the service brake, application of the emergency brake, trip characteristics, and rates of acceleration and retardation. To carry out the tests safely, the automatic contrivance is adjusted to control the speed of descent past an artificial landing, set equivalent to a point part way up the shaft. On completion of the tests the automatic contrivance is returned to its normal setting and its overwind switches are checked by raising each conveyance above the highest landing, to see that the overwind switches operate within a predetermined distance.

123 The Coal and Other Mines (Shafts, Outlets and Roads) Regulations 1960 require that drum winding engines be provided with brakes which will hold the drum stationary when loads are balanced and maximum torque is applied in either
direction; or, if there is only one conveyance, brakes which will hold the drum stationary when a fully loaded conveyance is halfway down the shaft and maximum torque is applied downwards. The value of torque applied during brake holding tests on electric winding engines has been subject to different interpretations, and the best practical methods of carrying out the tests were therefore examined.

124 The practice adopted for brake holding tests on electric winding engines is to use one of the following methods:

- with the current corresponding to maximum motor torque;
- with twice the full load current specified on the winding engine nameplate; or
- with 1.1 times the current taken by the motor when lifting the normal maximum load from the bottom of the shaft at the rate of acceleration specified for the duty cycle in use.

In the first two cases, motors which, for example, have been transferred from other installations may be able to develop torques much greater than the demands of the duty cycle, and application of these torques could lead to equipment damage or excessive braking. Some motors have current limiting devices to restrict the maximum torque they can produce; but, where these devices are not used, it is more satisfactory to use the third method for testing the mechanical brake because it demonstrates that the brake can meet service requirements with a margin of safety and without risk of damage to equipment. None of these static tests, however, measures the maximum torque which the brake produces and a more realistic test would be used on the power torque needed to begin to move the drum with the brake applied. Trials are being carried out to establish whether this alternative procedure is practicable.

125 A declared test load should be available for each winding installation to enable consistent statutory landing speed tests to be carried out. Its weight should be equal to that of the permitted maximum number of men per conveyance, based on 1.5 cwt (75 kg) per man, and should be checked at prescribed intervals. The test load should be such that it cannot be used for any other purpose or altered inadvertently in weight. It should be clearly identified, marked with the test weight, the equivalent number of men, and the identity of the winding system or systems with which it is to be used. Moreover it should be such that it can be brought easily to the shaft side and placed in the appropriate conveyance.

126 Recommendations:

1. Consideration be given to changing legislation to permit the maximum interval between statutory landing speed tests of winding engines equipped with category A automatic contrivances to be increased to six months.

2. The model testing code in Part 1B for drum winding engines be adopted.

3. Preparation of the friction winding engine model testing code be pursued with the intention of adopting it when completed.

4. The statutory brake holding requirements for electric drum winding engines be determined by a test carried out at the maximum current permitted by any current limiting device in use; and that, on those winding engines where no current limiting device is in use, the test be carried out at a current corresponding to 1.1 times the maximum torque required for normal duties, taking into account any permissible variation in loading conditions or changes in supply voltage; where a motor will not develop 1.1 times the maximum torque
required in service for normal duties, the test be carried out at the maximum
torque available to the winding engineman, and consideration be given to
amending legislation.

(5) The brake holding test for steam drum winding engines be carried out at such
crank positions as to ensure that the maximum torque (derived from the sum of
piston effort at maximum operating pressure multiplied by effective crank
radius) is applied to the drum.

(6) Brake holding tests for winding engines be carried out each shift to determine
that contamination has not reduced brake performance below the level defined
in paragraphs 126 (4) and 126 (5).

(7) That trials continue, to establish whether it is practicable to replace the existing
brake holding tests for electric winding engines by a test using a specified
combination of mechanical brake torque and power torque – such that the
drum just moves through the brakes.

**Training of winding enginemen**

127 The present system consists of operational training by nominated competent
winding enginemen and informal instruction given by mine engineering staffs and
others. The arrangement is well proven and should continue, except that the
training given by persons other than competent winding enginemen should be
formalised. Arrangements for instructing, training and examining winding enginemen
in safe and efficient operation of winding engines under their control have been
reviewed. Formal training should include a basic appreciation of the functions of
controls and safety equipment of winding engines which the winding engineman is
likely to operate. Such an appreciation would help to minimise differences in
winding techniques, but the main advantage would be to encourage the liaison
between winding enginemen and engineering staff of the mine necessary to
promote safe and efficient working. A suggested specification for operational and
formal training is in Part 1B.

128 The *maintenance information manual*, referred to in paragraph 102 should
contain material which can be extracted to form part of an *operating manual* for
winding enginemen. The latter manual should be prepared for each winding engine
and include:

- descriptions of the function of controls, indicators, instruments and various
  protective devices as far as they influence operation of equipment by winding
  enginemen;
- precautions to be observed by winding enginemen when carrying out their
  functions and duties; and details of safety or emergency procedures as far as
  they affect the operation of equipment by winding enginemen.

129 Each winding engineman should be issued with the operating manual(s) for
the winding engine(s) which he is required to operate, and a member(s) of the
engineering staff of the mine or other competent persons should be nominated to
give the formal training deemed necessary. When a competent winding engineman
is required to operate a winding engine with which he is not familiar, training
procedures as for new entrants should be adopted although the time to acquire
proficiency should be less.
130 Recommendations:

(1) A training specification for winding enginemen be established. A typical specification is in Part 1B.

(2) An administrative procedure for implementing the training specification be established which should include the recording of time spent by a trainee on supervised operation of winding engines.

(3) A certificate of competency be issued. This should be signed by the supervising winding engineman and the persons responsible for formal training on satisfactory completion of training, and then be countersigned by either the electrical or mechanical engineer of the mine, or both, as may be appropriate.

(4) Authorisation of the trainee as a competent winding engineman by the manager of the mine be based on the certificate of competency.

(5) An operating manual be prepared for each winding engine incorporating information and instructions relevant to operation of the winding engine by the winding engineman.

(6) Winding enginemen be issued with a copy of the operating manual for each winding engine which they are required to operate.

(7) A member of the engineering staff of the mine or other competent persons be nominated by the manager to give the requisite formal training to winding enginemen.

(8) Each operating manual be reviewed periodically to take account of any changes in operating arrangements or procedures.

**Winder testing engineers**

131 Procedures for testing winding engines are detailed in the testing codes referred to in paragraph 122. Testing of winding engines requires them to be operated outside their normal winding cycle and may subject the equipment to the limits of its design operating conditions. The tests must be performed in a safe and efficient manner and proper conclusions have to be drawn from the observations and results. It is not sufficient for the person carrying out the work to have only a knowledge of testing procedures and an ability to operate testing equipment. He must also have an understanding of the principles on which different safety systems are based, the functions of the various components of those systems, and the concepts of the design and controls – such as the basis on which permissible retardation rates for friction winding engines are determined, or the effects of different emergency tripping and braking arrangements.

132 In the past there was no uniform training programme for winder testing engineers who generally had suitable practical knowledge supplemented by operational training on the job. There were differences in test procedures but progressive development of the testing codes and use of common types of test equipment have led to greater uniformity which facilitates the establishment of a common training programme. For future selection for training, preference should be given to a person who has already had the practical training and experience equivalent to the standard of the Mechanics’ or Electricians’ Class I Certificates of the Mining Qualifications Board and academic qualifications in appropriate engineering standards to either the Higher National or AMEME Honours Certificates. However, some discretion concerning these qualifications, training and
experience should be allowed, so that a prospective testing engineer with necessary aptitude and appropriate practical background could be admitted with the minimum academic qualification of an Ordinary National Certificate in engineering subjects or its equivalent.

133 The principal duties of the winder testing engineer are described in Part 1B and the nature of these is such that operational training must form a major part of a training programme. At present this is provided by winder testing engineers in post. Formal technical instruction should also be given so that the trainee understands the design and operating principles of those winding engines with which he is to be concerned, to ensure safe and efficient testing. It is, however, necessary to formulate the scope and nature of operational training and technical instructions on a common basis and a suitable syllabus is in Part 1B. The progress of trainees should be reviewed by a nominated person at intervals of about three months.

134 The standard of competency of winder testing engineers in post is generally high; however, if consistent standards are to be assured, they and those being trained should be given a course of centralised training based on the technical instruction content of the syllabus. During this course, material included in the syllabus could be revised and developed into a manual to supplement the testing codes. These codes and the proposed manual could then form the basis of specialist training and should be regularly reviewed and updated. Winder testing engineers should also attend courses whenever necessary for instruction in new equipment and techniques.

135 On successful completion of training, winder testing engineers should be issued with a certificate of competency and would be authorised for the performance of their duties under Regulation 11 (1) (a) of the coal and Other Mines (Mechanics and Electricians) Regulations 1965.

136 Recommendations:

(1) The preferred academic standard for persons selected for training as winder testing engineers be the Higher National Certificate in appropriate engineering subjects or the Honours Certificate of the AMEME or equivalent.

(2) The persons selected should also have had practical engineering training and experience and that the training and experience required for the Mining Qualifications Board Mechanics or Electricians Class 1 Certificates be taken as an acceptable standard.

(3) Discretion be allowed to select persons for training who have a minimum qualification of an Ordinary National Certificate or equivalent in appropriate engineering subjects and who have had appropriate practical training and experience.

(4) The proposals for specialist training of winder testing engineers detailed in Part 1B be used as a basis for a formal scheme of training.

(5) A centralised course be organised for all existing winder testing engineers and persons presently being trained.

(6) The centralised course material be developed and made available as a manual to supplement the testing codes referred to in paragraph 122 and subsequently used with these codes as the basis of specialist training for future trainees. The manual should be regularly reviewed and updated.
(7) Winder testing engineers attend courses, as necessary, for instruction in new equipment and techniques.

(8) Winder testing engineers be issued with a certificate of competency signed by the superintending engineer on satisfactory completion of training prior to authorisation.

**Posted notices**

137 Consideration has been given to the nature and extent of information which should be posted and available in the winding engine house, at the shaft landings, and to notices required by regulations. Many proposals were examined but it was thought necessary to limit additional notices to those indicated in the recommendations below.

138 Recommendations:

1. A copy of the master record referred to in the testing code in Part 1B of the landing speed test for each winding engine be kept in the winding engine house and be available to those concerned, including the winding engineman.

2. It be the duty of the winder testing engineer to ensure that an up to date copy of the Master Record is available when he is carrying out routine tests.

3. A notice headed ‘Operating and Safety Instructions’ be posted in the winding engine house for each winding engine stating the maximum permissible speed when men are travelling: the winding engine motor current, or steam pressure and crank position, to be used for the brake holding test; and the winding engine motor current, or steam pressure, to be applied for the standing start test.

4. A notice headed ‘Operating and Safety Instructions’ be posted, at the surface landing(s) stating the maximum permitted load, the gravity winding loads, the test load for man landing speed tests and instructing that the winding of abnormal loads be supervised by the mechanical engineer of the mine or a person nominated by him.

5. A notice headed ‘Operating and Safety Instructions’ be posted at the pit bottom and at other entrances to the shaft, stating the maximum permitted load and instructing that the winding of abnormal loads be supervised by the mechanical engineer of the mine or a person nominated by him.

6. A footnote be added to notices headed ‘Operating and Safety Instructions’ stating that full operating and safety instructions are in the operating manual and details of the landing speed test in the master record.

7. A standard style of notice be adopted.

**Statutory requirements**

139 Requirements of the Mines and Quarries Act 1954 and regulations, under that Act concerning maintenance of winding engines have been reviewed. The other related requirements of the Act and regulations not directly concerned with safety of manriding in shafts and unwalkable outlets were also examined. Amendments have been suggested to a number of requirements in the Act and regulations, and proposals made to improve the standard and organisation of maintenance to secure effective compliance.
140 The proposed amendments together with references to other aspects of the Acts and regulations covered by the general considerations and recommendations of this report, have been submitted to the Health and Safety Executive and the National Coal Board for consideration of relevant sections as appropriate.

5 Other winding practices

Control systems: push button winding

141 Push button winding when men are carried is being examined, because of its potential for greater safety as the system of control is improved to provide consistent performance and winds are initiated from the shaft side or within the conveyance. Such control schemes have been in use for mineral winding for many years, and British and overseas manufacturers have supplied push button winding engines for man winding outside Great Britain. An examination was carried out of the types of winding engines listed in paragraph 27 to establish their suitability for push button operation. It is considered necessary to establish principles and codes of practice applicable to existing and future winding installations and this work is continuing.

142 AC WINDING ENGINES. These were examined, and those with a closed-loop control system appeared to be more suitable for modification to push button operation. Aspects investigated were acceptability of performance for man winding, and the effect of differing loads on rope speeds throughout successive winds. Technical literature on the subject was also considered, in conjunction with experience gained by manufacturers.

143 Published material shows that the inherent characteristics of these engines in some circumstances can produce unsatisfactory operational features of speed, loading and control system response. The results of tests carried out on two AC winding engines for this investigation showed that they did not respond satisfactorily under varying load conditions, the worst features being erratic and excessive rates of retardation and high landing speeds. These results together with a brief history of the development of closed-loop control, including an outline of major problems associated with control of AC winding engines, are in Part 1B.

144 DC WINDING ENGINES. Because of the inherent characteristics of their control systems these are more suitable for push button control than AC winding engines. Test of suitability of control systems for push button windings were made on two DC winding engines equipped with closed-loop control, one being supplied from a motor-generator set and the other from a mercury arc convertor. The results indicate that closed-loop control produces consistent performances over the range of man loads and the test results are in Part 1B.

145 Test results already available on DC winding engines with open-loop control were examined to ascertain whether this type of control is suitable for push button man winding. They showed wide variations performance and inconsistencies in landing speeds which render them unsuitable for this purpose.

146 Conclusions:

(1) AC WINDING ENGINES, at the present state of technology, are considered unsuitable for push button winding as man loads vary between successive winds. The adverse operational features are as follows:

- momentary loss of control and increase in speed occur when the system changes form the powered mode to the braking mode;
at creep speeds hunting can occur towards the end of the wind causing oscillations in the winding rope and discomfort for men in the conveyance; under lightly loaded conditions landing speeds can be excessive; and rates of retardation can be erratic and excessive owing to control system limitations.

(2) DC WINDING ENGINES with closed-loop control systems can be modified for push button control when winding men. However, where mineral and materials are also to be wound by push button control the system must be capable of accommodating the total variety of operational activities, such as consecutive decking, landing at insets, and manoeuvring the conveyances when loading long materials.

(3) DC WINDING ENGINES with open-loop control systems are considered unsuitable for push button control when winding men because of wide variations in performances and inconsistencies in landing speeds.

**Lift practice**

147 The mechanical and electrical aspects of lift practice were examined to ascertain if any of them could be applied to the winding of men in shafts, the push button control feature having been considered separately (see paragraphs 141 to 146). A study was made of the relevant parts of British Standard 2655: Part 1 1970 ‘Specification for lifts, escalators, passenger conveyors and paternosters – general requirements for electric, hydraulic and hand powered lifts’, in comparison with winding practice. Experience with lifts in industrial and similar premises, and in South African mines, was also considered.

148 Most modern passenger lifts in buildings have a single car and counterweight running on rigid guides, with multi-rope friction drive, powered by a direct coupled DC motor. Open-loop Ward Leonard control is used and is suitable because the range of car loads and speed are generally less than with winding installations. Doors at landings and on cars are mechanically locked and electrically interlocked. Acceleration, retardation and final stopping are automatically controlled, and at the terminal doors, retardation and stopping are shadowed by a back-up system. Controls, lighting, telephone and alarm facilities in the car are supplied through suspended cables; positive indication of the position of the car and its control are achieved by a slotted steel tape or similar connector between the car and the floor selector control in the machinery room. Electrical overwind protection is by limit switches operated by the car, and overspeed protection is provided by a single mechanical governor in the lift engine room driven by friction from a continuous rope attached to the car. The first stage of overspeed protection is designed to reduce motor speed electrically; the second, to apply the mechanical brake while retaining controlled electrical braking; and the third, by means of the governor rope, to trip the conveyance safety-gear under the floor of the car to grip the guide rails. The significance of conveyance safety-gear in winding practice is discussed in the subsection commencing at paragraph 153. Energy absorbing buffers are an additional protection installed in the well of a lift shaft where a conveyance operated final limit switch causes the lift engine to be shut down.

149 Lift shafts are not generally used to accommodate other services and the environment in these shafts can be conditioned to ensure operation to designed standards. Moreover the maximum parameters known used in lift practice in buildings are:
While accident statistics for lifts show a decreasing trend, serious injuries and fatalities continue to occur.

150 Lifts are used to carry persons through mine shafts and the maximum parameters known for this practice are:

- **Speed:** 26 ft/sec (8 m/sec);
- **Shaft depth with suspended cable control:** 1600 ft (486 m);
- **Power:** 450 hp (336 kW).

Conveyance safety-gear is not provided on conveyances in shafts deeper than about 1600 ft (486 m) and not usually in shafts deeper than 1000 ft (304 m). Slotted tape is not used at depths greater than about 1600 ft (486 m) and the floor selector control is driven instead from the lift engine. Proximity switches are then used to check and prove the position of the car at each landing and rope creep compensation is provided at the approach to each terminal landing. The limit for suspended cable is again approximately 1600 ft (486 m) although radio control has apparently proved satisfactory at greater depths. In South African coalmine shafts, the position of a lift car relative to the floor selector control is continually checked and adjusted by cam operated switches, either in the shaft or on the car, and consequently rigid guides are always used. Doors on cars and at landings are operated manually and interlocked with the lift control system. Environmental conditions have caused considerable problems particularly in upcast shafts.

151 Conclusions:

1. Lifts are not appropriate for general mine winding duties because of a number of features including limited capacity and speed. However, a lift for passengers only could be installed at a new or reconstructed mine shaft provided the environment is suitable for the apparatus.

2. A passenger lift should not be installed in a mine shaft unless, as a minimum, all the safeguards provided for lifts in buildings are incorporated.

3. An engineering principle of lift practice which could be adopted with advantage in winding installations is the use of buffers for arresting a descending conveyance (see paragraphs 53 – 60).

4. There are few significant differences in essential electrical safety practices between the best winding practices and the best lift practices, but lift practices have been formalised in standards whereas British winding practices have not. This report will, however, do much to formalise winding practices.

152 Recommendation:

That the principle of shaft bottom buffers as used in lift practice be adopted in winding practice.

**Conveyance safety-gear in mine shafts**

153 In evidence given before the public inquiry into the Markham accident, protection afforded to persons travelling in a descending lift conveyance in a tall...
building was compared with that in a mine shaft. Comments were based on the fact that every lift conveyance is provided with conveyance safety-gear which, in the event of overspeed in the downward direction, or failure of the ropes or suspension gear, grips the guides and brings the conveyance to rest. Members of the public suggested methods of arresting run-away conveyances in both rigid guided and rope guided shafts. Each suggestion was carefully considered but most were not suitable for application to mine shaft winding installations.

154 Experience with conveyance safety-gear of the type described in paragraphs 148 and 150 is largely restricted to lifts running in specially constructed compartments with favourable environments. However, the environment in the majority of mine shafts can only be regarded as extremely hostile compared with that of lift compartments in buildings, and could seriously impair the reliability and efficiency of conveyance safety-gear. Moreover, conveyance safety-gear is not normally fitted to lifts in mines when the depth exceeds about 1000 ft (304 m), the limit is about 1600 ft (486 m), at which depth inertia of the operating rope can cause inadvertent operation of the device.

155 Conveyance safety-gear has never been required by law in mine shafts in Great Britain or favoured as a means of protecting persons. It has been the practice to rely on the mechanical brake of the winding engine, the automatic contrivance and on the integrity of the winding rope and suspension gear. This practice, combined with a high standard of inspection and maintenance, has virtually eliminated failures in service.

156 Practice overseas where conveyance safety-gear in mine shafts is or has been mandatory were studied. Many forms of conveyance safety-gear have been used on mine winding installations with fixed guides, designed to grip the guides and bring the conveyance to rest in the event of breakage of a winding rope or suspension gear. The Government of the Province of Ontario, Canada, appears to be the only authority still to require by law that conveyance safety-gear is fitted and tested, even though 16 persons were killed in 1945 in a mine accident when the conveyance safety-gear failed to operate. A year later in Germany, when conveyance safety-gear was a legal requirement, 45 persons were killed when conveyance safety-gear failed to prevent the conveyances from falling to the bottom of the shaft after failure of a rope attachment. A comprehensive survey carried out in Germany showed that in the period 1945 – 1954 only one out of 20 required operations of conveyance safety-gear was successful and in the same period there were 46 inadvertent operations during normal winding. It was concluded that the failure of these devices to operate when required, and the very real dangers associated with frequent inadvertent operation, render conveyance safety-gear unsuitable for man winding. In 1957 the law in Germany was amended so that conveyance safety-gear is no longer required and within a few years all conveyance safety-gear was removed.

157 If conveyance safety-gear is fitted, it seems that serous danger can result from its inadvertent operation when a conveyance is descending a mine shaft. The conveyance would initially be arrested and held on the guides, slack rope could accumulate and in the event of subsequent failure of the device the conveyance could fall freely down the shaft. Should a balance rope be connected to the underside of the two conveyances in a winding system and the same circumstances obtain with the descending conveyance, then continued movement of the ascending conveyance could cause the balance rope to tighten around a shaft bottom structure with dire results. Moreover, conveyance safety-gear of the types described in the previous paragraph, which are designed to operate on failure of a rope or suspension gear, would offer no protection in the event of overspeeding of the winding engine, as happened at Markham Colliery.
158 Conclusion:

Rather than adopt conveyance safety-gear the present practice, which relies on maintaining the integrity of the primary system, should continue. This is achieved by careful attention to design and maintenance of winding engine, ropes and conveyance suspension gear. This agrees with the conclusion of the Conference on the Use of Wire Ropes in Mines held in 1950 under the auspices of the Institution of Mining and Metallurgy, and with present German practice.

159 Recommendation:

That the present practice which relies on maintaining the integrity of the primary system continue rather than adopt conveyance safety-gear.

**Related Continental safety aspects**

160 To extend the scope of this report, two teams of engineers comprising sub-committee and working group members visited Germany, and three continental manufacturers attended specially convened meetings in London. During the visit to Germany and the specially convened meetings, discussions were concentrated on winding practices related to safe operation. Information was particularly sought on any safety devices or practices which were not already in use in Great Britain and could be considered for adoption. Before the visits to Germany, questions were submitted by sub-committees to assist the teams. These questions and the resulting findings are included in the visit reports in Part 1B.

161 The programme for the teams included visits to the Seilprüfstelle (rope testing station) of the West-fälische Berggewerkschaftskasse (WBK), Tremonia experimental mine, and to coal, metalliferous and potash mines. During visits to the producing mines, representatives of the winding equipment manufacturers were present to assist with technical discussion.

162 WBK is a private organisation established by law in 1863 but dating in its present form from 1912 before which its main function had been to assist in the improvement of rope standards. Since 1912 the responsibilities of the institute have been extended to include, among other things, safety assessments of complete winding installations, and later to issue certificates of compliance with the requirements of relevant regulations and official design criteria. In addition, it carries out research and development, particularly in connection with ropes and is responsible for training of winding enginemen and some other personnel.

163 Tremonia is a non-producing mine retained solely for experimental purposes. One shaft is equipped with a winding installation which provides testing facilities for differing types of brake gear, shaft and other equipment. At the three producing mines visited, opportunity was taken to examine and discuss safety features and maintenance procedures with users and manufacturers. Meetings with the German Mines Inspectorate (CMA) were not possible at the time of the visits, so the implications of new German winding regulations which are being prepared could not be discussed.

164 The meetings held in London with three Continental manufacturers prior to the visits to Germany resulted in the acquisition of useful information which was corroborated during the visits.

165 Observations:

(1) German philosophies, practices and apparatus, discussed or seen, do not suggest any reason to change radically the philosophies and principles being
recommended by this Committee. However, it would be prudent to be associated with development work now proceeding in Germany on non-destructive testing of ropes, comparison between shoe and disc brakes, and visual indication of forces in brake tie rods.

(2) German practice with a closed-loop system of control provides a means of supervising the speed control loop with overall protection by a supervisory device, however, further investigation is necessary to establish the degree of independence between the control and supervisor circuits using this practice.

(3) Control of a DC winding engine from the conveyance through an inductive loop system is operating effectively in Germany for the carriage of men. This subject is being studied (paragraphs 141 – 146 refer).

(4) The German practice of having a design appraisal and a manual for each winding engine supports proposals in this report; moreover winding engine defects are recorded and the information is used as an aid to design and reliability.

(5) The German Mines Inspectorate (CMA) in the course of their duties are concerned not only with investigation and recording of winding engine accidents and incidents, but also with approval of design details of winding equipment.

166 Recommendations:

(1) The German practice of supervisor closed-loop control be compared with proposals in this report that safety circuits be separated from the normal means of control and that automatic contrivances and protective equipment be either monitored or supervised (paragraphs 41, 42 and 45 refer).

(2) The proposed new German winding regulations be studied.

(3) A system being used in France to continuously monitor the position of a conveyance in a shaft be investigated.

6 Abstract of Recommendations

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<th>Paragraph</th>
<th>Recommendation</th>
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<td>Mechanical brake design</td>
<td>14</td>
<td>The design of mechanical brakes for winding engines be based on the design guide referred to in Part 1B.</td>
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<tr>
<td>Mechanical brake: materials and construction</td>
<td>20(1)</td>
<td>The materials listed in the table in Part 1B be used in the construction of winding engine brake gear.</td>
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<td></td>
<td>20(2)</td>
<td>Materials be identified by reference to British Standards. (Where this is not possible for some proprietary items, or because of new developments, the supplier should submit details of materials and their treatment to the customer for approval).</td>
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<td>20(3)</td>
<td>The materials used be of such quality that components manufactured from them satisfy the non-destructive testing requirements outlined in Part 1B.</td>
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<td>20(4)</td>
<td>Agreed quality control procedures be used during fabrication and casting.</td>
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<td>20(5)</td>
<td>Tests and other criteria be specified in the contract.</td>
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<td>Subsection</td>
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<tr>
<td>Mechanical brake: general requirements</td>
<td>20(6)</td>
<td>Test certificates and/or other forms of quality assurance be obtained.</td>
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<td>and essential features</td>
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<td></td>
<td>23(1)</td>
<td>The general requirements in Part 1B for new mechanical brakes for winding engines be adopted.</td>
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<td></td>
<td>23(2)</td>
<td>The essential features from the general requirements, as in Part 1B, be applied to mechanical brakes on existing winding engines.</td>
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<tr>
<td>Electrical braking: retention</td>
<td>33(1)</td>
<td>The objective be pursued for DC and AC winding engines that after the initiation of an emergency or automatic trip, electrical braking is retained without the intervention of the winding engineman until the mechanical brake is proved substantially effective.</td>
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<td>33(2)</td>
<td>A torque control scheme for the automatic application of dynamic braking without the intervention of the winding engineman be further developed; and that one winding engine in category VII be fitted with such a scheme, to gain experience prior to any firm recommendation’s being made about the future of winding engines in this category.</td>
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<td></td>
<td>33(3)</td>
<td>Electrical control schemes of DC winding engines in categories IV and V be brought up to the standards of those winding engines in categories I or II.</td>
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<td></td>
<td>33(4)</td>
<td>Consideration be given to uprating the electrical control scheme of DC winding engines in category III to the standards of those winding engines in categories I or II to take advantage of the improved control.</td>
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<td>33(5)</td>
<td>AC winding engines in category VIII be equipped with dynamic braking wherever practicable to bring them to the standards at least of category VII in which dynamic braking remains available for manual application by the winding engineman after an emergency or automatic trip.</td>
</tr>
<tr>
<td>Automatic contrivances</td>
<td>42(1)</td>
<td>An automatic contrivance be used on every winding engine that has a normal maximum winding speed greater than 5 ft/sec (1.6 m/sec).</td>
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<td>42(2)</td>
<td>The use of simple overspeed devices, which trip at a single speed only, be limited to winding engines with a normal maximum winding speed not exceeding 5 ft/sec (1.6 m/sec).</td>
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<td>42(3)</td>
<td>Automatic contrivances in categories B and C listed in part 1B be replaced.</td>
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<td>42(4)</td>
<td>Certain details of design of automatic contrivances in category A be improved as scheduled in Part 1B.</td>
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<td></td>
<td>42(5)</td>
<td>Automatic contrivances of new or modified design be critically appraised before they are accepted for use.</td>
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<td>42(6)</td>
<td>Automatic contrivances and protective equipment be monitored or a separate supervisor device be provided.</td>
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<td>42(7)</td>
<td>Where a simple overspeed device is used on those winding engines that have a normal maximum winding speed not exceeding 5 ft/sec (1.6 m/sec) a second separately driven overspeed switch be used as an alternative to monitoring.</td>
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<td></td>
<td>42(8)</td>
<td>The drive to any monitoring or supervisory device be separate from the drive to the equipment being monitored or supervised.</td>
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<td></td>
<td>42(9)</td>
<td>The monitoring system or supervisory device cause the winding engine to be brought safely to rest in the event of failure of the drive to the protective equipment.</td>
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### Safety circuits

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<th>Paragraph</th>
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<td>47(1)</td>
<td>Abnormal conditions be classified in three categories as follows:</td>
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<td>Category 1 dangerous to persons in a conveyance if not dealt with immediately;</td>
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<td>Category 2 dangerous to persons in a conveyance if allowed to persist;</td>
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<td>Category 3 injurious to plant;</td>
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<td>and that automatic protection appropriate to these conditions be provided.</td>
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<td>47(2)</td>
<td>Each part of the safety circuit associated with categories 1 and 2 should have at least two contactors energised by the circuit and should not use single line components for essential functions.</td>
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<td>47(3)</td>
<td>Each pair of contactors be monitored and cross interlocked so that failure of any one to function correctly is automatically indicated and/or prevents the continuation of winding.</td>
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<td>47(4)</td>
<td>Both parts of the safety circuit associated with category 1 be in conductors having individual conducting screens, all screens being earthed; and that these parts of the safety circuit be physically segregated one from the other and from any other circuit to avoid malfunction caused by leakage or induction.</td>
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<td>47(5)</td>
<td>A reliable system of earth fault protection be provided for safety circuits.</td>
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<td>47(6)</td>
<td>Ancillary circuits, indicator circuits, backing out circuits etc, connected to a safety circuit, be provided with the same protection against malfunction as the safety circuit.</td>
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<td>47(7)</td>
<td>In those installations where winding of abnormal loads, eg long loads, conflicts with normal overwind protection, specific arrangements to be made (as in paragraph 64) and formal procedures established for this to be done without risk of lowering the level of safety afforded by the normal overwind protection when man winding is resumed.</td>
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### Rope speed indicators

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<td>49(1)</td>
<td>Rope speed indicators be fitted to all winding engines.</td>
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<td>49(2)</td>
<td>For a winding engine with a bi-cylindro conical drum, calibration of the rope speed indicator be related to the largest diameter of the drum except where other practice is already established at the mine.</td>
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<tr>
<td>49(3)</td>
<td>The maximum permissible speed when men are travelling be displayed in the winding engine house.</td>
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<td>49(4)</td>
<td>The maximum permissible speed when men are travelling, and the normal maximum winding speed, be marked on the scale of the rope speed indicator.</td>
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### Pit bottom buffers

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<tr>
<td>60</td>
<td>Development work be continued, so that buffers of suitable design are available for installing in pit bottoms of all drum winding installations.</td>
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### Headframe ultimate limit switches

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<td>65(1)</td>
<td>Headframe ultimate limit switches, operated directly by a conveyance, designed to initiate cutting off all power from the winding engine and initiate application of the mechanical brake, be provided for all winding installations.</td>
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<tr>
<td>65(2)</td>
<td>Headframe ultimate limit switches are of the mechanically operated heavy duty type, protected against weather, capable of withstanding normal operating impacts by conveyances, and have contacts driven positively to the open position; or be equally effective alternative devices.</td>
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<td>Subsection</td>
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<td>Safe manriding in mines: First Report of the National Committee for Safety of Manriding inshaftsan d Unwalkable Outlets</td>
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<td>130(2)</td>
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<td>130(7)</td>
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<td>130(8)</td>
</tr>
<tr>
<td>Winder testing engineers</td>
<td>136(1)</td>
</tr>
<tr>
<td>Subsection</td>
<td>Paragraph</td>
</tr>
<tr>
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<tr>
<td>136(2)</td>
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<td>136(3)</td>
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<td>136(4)</td>
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<td>136(5)</td>
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<td>136(7)</td>
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<td>136(8)</td>
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</tr>
</tbody>
</table>

**Posted notices**

<table>
<thead>
<tr>
<th>Subsection</th>
<th>Paragraph</th>
<th>Recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>138(1)</td>
<td></td>
<td>A copy of the master record referred to in the testing code in Part 1B of the landing speed test for each winding engine be kept in the winding engine house and be available to those concerned, including the winding arrangements.</td>
</tr>
<tr>
<td>138(2)</td>
<td></td>
<td>It be the duty of the winder testing engineer to ensure that an up to date copy of the Master Record is available when he is carrying out routine tests.</td>
</tr>
<tr>
<td>138(3)</td>
<td></td>
<td>A notice headed ‘Operating and Safety Instructions’ be posted in the winding engine house for each winding engine stating the maximum permissible speed when men are travelling; the winding engine motor current, or steam pressure and crank position, to be used for the brake holding test; and the winding engine motor current, or steam pressure, to be applied for the standing start test.</td>
</tr>
<tr>
<td>138(4)</td>
<td></td>
<td>A notice headed ‘Operating and Safety Instructions’ be posted, at the surface landing(s) stating the maximum permitted load, the gravity winding loads, the test load for man landing speed tests and instructing that the winding of abnormal loads be supervised by the mechanical engineer of the mine or a person nominated by him.</td>
</tr>
<tr>
<td>138(5)</td>
<td></td>
<td>A notice headed ‘Operating and Safety Instructions’ be posted at the pit bottom, and at other entrances to the shaft, stating the maximum permitted load and instructing that the winding of abnormal loads be supervised by the mechanical engineer of the mine or a person nominated by him.</td>
</tr>
<tr>
<td>138(6)</td>
<td></td>
<td>A footnote be added to notices headed ‘Operating and Safety Instructions’ stating that full operating and safety instructions are in the operating manual and details of the landing speed test in the master record.</td>
</tr>
<tr>
<td>138(7)</td>
<td></td>
<td>A standard style of notice be adopted.</td>
</tr>
</tbody>
</table>

**Lift practice**

<table>
<thead>
<tr>
<th>Subsection</th>
<th>Paragraph</th>
<th>Recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>152</td>
<td></td>
<td>That the principle of shaft bottom buffers as used in lift practice be adopted in winding practice.</td>
</tr>
</tbody>
</table>
7 Future work

167 The introduction to this report, referred to the scope of investigations. Part 1 has been produced as an interim statement of completed work with conclusions and recommendations. Those matters thought to be most significant have been considered first and the results are published in this report. All the subject matter relating to the original terms of reference has not yet been completed. Outstanding matters, and other related subject, have been allocated to sub-committees and working groups for their continued attention, and results of these subsequent deliberations will be published separately in further parts of this report.

168 Work which is still outstanding from Part 1, and new subjects to be considered are as follows:

(1) Work still to be completed

PIT BOTTOM BUFFERS
Further development and testing.

FRICITION WINDING ENGINES
Completion of testing code.

MECHANICAL BRAKE
Investigation into performance tests.

Preparation of design guide.

Investigation of failures.

Development of torque measuring device.

BRAKE LININGS
Review of materials.

Brake control system.

Consideration of electrical/mechanical interface.

AUTOMATIC CONTRIVANCES
Investigation into supervisory device/monitoring and other electrical aspects.

CAGE POSITION MONITORING
Development of system.
SHAFT SIDE EQUIPMENT
Interlocking of decking plant and inset equipment.

SLACK ROPE PROTECTION
Development of new systems.

SHAFT SIGNALS
Improvement of present systems.

CONTROL SYSTEMS
Introduction of push button winding.

NON-DESTRUCTIVE TESTING
Procedure for winding engine drums and other parts.

SYSTEMS RELIABILITY ASSESSMENT
Completion of pilot exercise.

MANDATORY REQUIREMENTS
Review.

(2) New subjects to be considered

FRICION WINDING ENGINES
Improved treads with better friction properties, review of creep compensation devices.

SHAFT SIDE EQUIPMENT
Review of maintenance of decking plant and inset equipment.

VEHICLE IN CAGE PROVING EQUIPMENT
Further development.

BALANCE ROPE
Review and development of loop monitoring.

CONTROL SYSTEMS
Analysis in relation to operational safety.

WINDING ENGINE MOTORS
Review of constructional aspects.

NEW GERMAN REGULATIONS
Review.

MANRIDING OTHER THAN IN SHAFTS
Review and recommendations.

Acknowledgements

The National Committee thank all persons and organisations who have contributed to this report. Many, at home and abroad, have given freely of their time, and organisations have generously afforded facilities, without which this report could not have been produced. Organisations include the National Coal Board, manufacturers of winding apparatus, manufacturers of lifts, unions and associations.
# Glossary

## Definitions of terms as used in this report.

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC</td>
<td>Alternating current.</td>
</tr>
<tr>
<td>Acceleration relief</td>
<td>A directional feature on an automatic contrivance which enables the conveyances of a winding installation to be wound away from a landing at a greater rate than the slow approach protection would otherwise enforce.</td>
</tr>
<tr>
<td>AC winding engine</td>
<td>A winding engine using one or more three phase induction motors to drive the drum or sheave.</td>
</tr>
<tr>
<td>AMEME</td>
<td>The Association of Mining Electrical and Mechanical Engineers.</td>
</tr>
<tr>
<td>Artificial landing</td>
<td>A level above the lowest landing of a shaft at which conveyance landing speed tests can be carried out safely on a winding engine by setting the automatic contrivance as though that level were the lowest landing.</td>
</tr>
<tr>
<td>Automatic contrivance</td>
<td>Apparatus provided on a winding engine to detect the condition and to initiate bringing conveyances to rest in the event of: overspeeding, approaching the lowest landing at an excessive speed; and travel beyond pre-determined limits above the highest landing.</td>
</tr>
<tr>
<td>Bi-cylindro conical drum</td>
<td>A winding engine drum on which a rope is carried on two parallel sections of different diameters and an interconnecting scrolled conical section.</td>
</tr>
<tr>
<td>Brake lock</td>
<td>A lock on the mechanical brake of a winding engine which is engaged when the brake is fully applied and prevents the brake from being released.</td>
</tr>
<tr>
<td>Cam gear</td>
<td>Cam gear driven by a drum or sheave of a winding engine which limit the maximum acceleration and the minimum rate of retardation of the drum or sheave at the ends of the wind irrespectively of the actions of the winding enginerman.</td>
</tr>
<tr>
<td>Capel or capping</td>
<td>The attachment fitted at the end of a steel wire rope by means of which the rope is coupled to any conveyance or apparatus.</td>
</tr>
<tr>
<td>Closed-loop</td>
<td>A self regulating control system in which the output is monitored and automatically corrected to the output value desired.</td>
</tr>
<tr>
<td>Clutched drum winding engine</td>
<td>A winding engine having a drum or drums which can be disconnected from the drive for the purpose of adjusting the depth of winding.</td>
</tr>
<tr>
<td>Common mode failure</td>
<td>Where identical parallel control systems or devices are utilised to provide against failure, a similar fault in each is described as a common mode failure.</td>
</tr>
<tr>
<td>Compounding</td>
<td>Mechanical braking may be applied to a drum or sheave at the same time as driving or braking torque from a prime mover of the winding engine. This is referred to as compounding and the resultant torque applied to the drum from these sources is their algebraic sum.</td>
</tr>
<tr>
<td>Contamination</td>
<td>Brake paths and linings of winding engines can become contaminated by oil, water, grease, chemicals, or the environment etc. Contamination or overheating reduces friction between brake paths and linings below the designed value so that for a given brake force the brake torque achieved is less than that anticipated.</td>
</tr>
<tr>
<td>Convertor supplied winding engine</td>
<td>A DC winding engine in which the supply for the DC winding engine motor(s) is obtained from an AC supply through a grid controlled mercury arc or thyristor convertor equipment.</td>
</tr>
<tr>
<td>Term</td>
<td>Definition</td>
</tr>
<tr>
<td>-------------------------------</td>
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</tr>
<tr>
<td>Conveyance</td>
<td>Any car, carriage, cage or skip in which persons, mineral or materials are wound through a shaft, and any counterweight.</td>
</tr>
<tr>
<td>Conveyance safety-gear</td>
<td>Apparatus placed beneath the platforms of lift cars and designed to grip each fixed guide when operated by a governor rope. Where similar apparatus has been used on mine shaft conveyances, it has generally been mounted on top of the conveyance and designed to be triggered by slackening of the conveyance suspension gear.</td>
</tr>
<tr>
<td>DC</td>
<td>Direct current.</td>
</tr>
<tr>
<td>DC winding engine</td>
<td>A winding engine using one or more direct current motors to drive the drum or sheave.</td>
</tr>
<tr>
<td>Definitive life</td>
<td>The definitive life for a component is the prescribed period between when it is first put into service and when it must be withdrawn from service. The period is of such duration that failure should not occur in service as determined by consideration of the design of the component in relation to its duty and working environment including any previous experience available.</td>
</tr>
<tr>
<td>Design guide</td>
<td>A proposed document for giving guidance on the desk of mechanical brakes of winding engines: for use by the National Coal Board and the Health and Safety Executive in conjunction with manufacturers of mechanical brakes for winding engines.</td>
</tr>
<tr>
<td>Detaching hook</td>
<td>A device located between the end of a winding rope and a conveyance such that in the event of an overwind an ascending drum wound conveyance is detached from the rope and held in the headframe.</td>
</tr>
<tr>
<td>Drum winding installation</td>
<td>A winding installation in which the rope for a conveyance is fastened at one end to the drum of a winding engine so that it is wound on or off as the drum is rotated.</td>
</tr>
<tr>
<td>Dynamic braking</td>
<td>A means of obtaining controlled electrical braking by utilising an AC winding engine motor as a generator by replacing AC power to its stator with a DC excitation and using the rotor resistance controller to control the braking and dissipate the energy.</td>
</tr>
<tr>
<td>Friction winding installation</td>
<td>A winding installation in which a rope or ropes are attached to a conveyance at each end and in which movement of the conveyances is produced by friction between the rope or ropes and the treads of a drive drum or sheave of a winding engine.</td>
</tr>
<tr>
<td>g</td>
<td>The acceleration due to gravity: ie 32.2 ft/sec² (9.81 m/sec²).</td>
</tr>
<tr>
<td>Headframe bell</td>
<td>An apparatus in a headframe which operates a detaching hook in the event of an overwind and from which the detached conveyance can be suspended depending upon the position of any safety catches provided.</td>
</tr>
<tr>
<td>Headframe ultimate limit switch</td>
<td>A switch positioned in a headframe above the highest terminal decking level, and operated by a conveyance in the event of an overwind beyond the point at which the overwind switches on the automatic contrivance are operated.</td>
</tr>
<tr>
<td>hp</td>
<td>Horsepower.</td>
</tr>
<tr>
<td>Infinite fatigue life</td>
<td>A component is said to be designed for an infinite fatigue life when the calculated stress conditions are such that failure from fatigue of the component under specified service conditions should theoretically never occur, ie the number of duty cycles that can be withstood may be regarded as infinite. Dependent on circumstances a component (in particular a single line component) may be designed for infinite life but put into service with a prescribed definitive life as a further safeguard.</td>
</tr>
</tbody>
</table>
Keps
Retractable arms or shoes in a shaft on which a conveyance may rest and which are normally inserted each wind to register the conveyance at a landing.

kW
Kilowatt.

Landing
Any shaft entrance normally used by men to enter or leave a conveyance.

Maintenance check list
A document specifying the nature of examinations and maintenance to be carried out at prescribed intervals on an item of mechanical or electrical apparatus.

Maintenance Information Manual
A manual proposed for each winding engine containing information necessary to assist engineering staff in maintaining the winding engine effectively.

Manager's scheme for the mine
A scheme of planned examination and testing, as required by the Coal and Other Mines (Mechanical and Electricians) Regulations 1965, to secure effective maintenance of mechanical and electrical apparatus at a mine.

Markham Official Report
The report on the case of, and circumstances attending, the overwind at Markham Colliery, Derbyshire, on 30 July 1973; by HM Chief Inspector of Mines and Quarries (Her Majesty's Stationery Office, London, Cmd 5557, April 1974).

Master Record
A record of the performance characteristics of a winding engine made at the time of its last commissioning or re-commissioning including landing speed tests.

Mechanical brake
Members which transmit force from springs, fluid or a weight(s) to braking surfaces of a drum or sheave of a winding engine, to bring the drum or sheave to rest and to hold the drum or sheave at rest by action of brake friction linings on brake paths.

Mechanical brake critical component
A component the failure of which will result in the loss of at least 50% of braking area or force on a winding engine.

Mechanical brake force
The total of forces applied to the brake shoes of a winding engine drum or sheave by the operating medium of the mechanical brake.

Mechanical brake torque
The total torque exerted on a moving drum or sheave of a winding engine by the mechanical brake. For a given drum or sheave, mechanical brake torque is proportional to the mechanical brake force multiplied by the coefficient of friction between brake linings and braking surfaces. Coefficients of friction may vary.

Non-destructive testing
Methods of testing components which do not affect their physical state. For winding engine components, magnetic particle, dye-penetrant and ultrasonic techniques are the most usual forms of non-destructive testing applied to detect cracks and other defects not visible to the naked eye.

Normal maximum winding speed
The maximum conveyance speed which should not be exceeded when normal loads are wound.

Oil servo assistance
A hydraulic device interposed between the winding engineman's control lever and control apparatus to assist and govern operation of the control apparatus.

Open-loop
A control system in which the output is not automatically self regulating.

Operating Manual
A proposed manual for each winding engine incorporating information and instructions relevant to operation of the winding engine.
<table>
<thead>
<tr>
<th>Term</th>
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<tbody>
<tr>
<td>Overwind</td>
<td>Unintentional overtravel of a conveyance beyond normal terminal decking levels or high speed contact of a conveyance with an arrestor or solid landing at pit bottom.</td>
</tr>
<tr>
<td>Public Inquiry</td>
<td>The Public Inquiry into the accident at Markham Colliery on 30 July 1973 held at Chesterfield between 10 and 15 October 1973.</td>
</tr>
<tr>
<td>Push button winding</td>
<td>Winding in which travel is initiated from the shaft side or within a conveyance and in which the wind is completed automatically.</td>
</tr>
<tr>
<td>Reverse current braking</td>
<td>Electrical braking of AC motors by reversing the phase rotation or their supply.</td>
</tr>
<tr>
<td>Single line component</td>
<td>A critical component the failure of which to function as designed renders a system totally inoperative.</td>
</tr>
<tr>
<td>Steam winding engine</td>
<td>A winding engine which is driven by steam. Remarks made concerning this type of engine can refer equally to winding engines driven by compressed air.</td>
</tr>
<tr>
<td>Testing codes</td>
<td>Testing codes, incorporating statutory tests, for the periodic performance testing of drum and friction winding engines.</td>
</tr>
<tr>
<td>Transducer</td>
<td>A device for detecting and measuring a condition and converting the information into a signal.</td>
</tr>
<tr>
<td>Treads</td>
<td>Material on the drum or sheave of a friction winding engine, grooved to accept the winding rope(s), to provide frictional drive.</td>
</tr>
<tr>
<td>Ward Leonard winding engine</td>
<td>A DC winding engine with speed control derived from supplying the armature of the DC winding engine motor(s) from a variable voltage DC generator(s) driven at constant speed by an AC motor fed from the electricity supply.</td>
</tr>
</tbody>
</table>
### APPENDIX  Sub-committee/Working groups/Drafting panel

<table>
<thead>
<tr>
<th>Member</th>
<th>Official Designation</th>
<th>Organisation</th>
<th>Other Committees</th>
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<tbody>
<tr>
<td><strong>Sub-committee 1 (SC1) - Mechanical Engineering</strong></td>
<td></td>
<td></td>
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<tr>
<td>T K Clanzy (Chairman)</td>
<td>HM Principal Inspector of Mechanical Engineering</td>
<td>HMI M &amp; Q</td>
<td>NC</td>
</tr>
<tr>
<td>J W Barnes</td>
<td>Area Chief Engineer, Western Area</td>
<td>NCB</td>
<td>WG1B</td>
</tr>
<tr>
<td>J A Feirm</td>
<td>Area Mechanical Engineer, South Notts</td>
<td>NCB</td>
<td>WG1C</td>
</tr>
<tr>
<td>E H Hands</td>
<td>Joint Managing Director</td>
<td>Blacks</td>
<td>SC4 WG1A</td>
</tr>
<tr>
<td>H M Harrison</td>
<td>Mechanical/Electrical Inspector</td>
<td>NUM</td>
<td>NC SC2</td>
</tr>
<tr>
<td>L C James</td>
<td>Head of Technical Services Division</td>
<td>MRDE</td>
<td>SC4 WG1A, 4B</td>
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<tr>
<td>R W Latham</td>
<td>Section Engineer</td>
<td>GEC</td>
<td>WG1C</td>
</tr>
<tr>
<td>E Loynes</td>
<td>Representative</td>
<td>AMEME</td>
<td>NC SC2 WG2B</td>
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<tr>
<td>H D Munson</td>
<td>Senior Principal Scientific Officer</td>
<td>SMRE</td>
<td>NC SC4</td>
</tr>
<tr>
<td>H A W Pettinger</td>
<td>Director</td>
<td>Otis</td>
<td>SC2 WG2E</td>
</tr>
<tr>
<td>H Starr</td>
<td>HM Senior Inspector of Mechanical Engineering</td>
<td>HMI M &amp; Q</td>
<td>SC3 WC3A, 3B</td>
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<tr>
<td>G E Winder</td>
<td>Principal Scientific Officer</td>
<td>SMRE</td>
<td>WG1A, 4B</td>
</tr>
<tr>
<td>P Wood</td>
<td>Head of HQ Shafts and Winding Section</td>
<td>NCB</td>
<td>WG1C DP</td>
</tr>
<tr>
<td>R F Young (Secretary)</td>
<td>HM District Inspector</td>
<td>HMI M &amp; Q</td>
<td>NC SC2, 3, 4, WG2D, 2E, 4C(E)</td>
</tr>
</tbody>
</table>

| **Sub-committee 2 (SC2) – Electrical Engineering** | | | |
| R Harthill (Chairman) | Chief Electrical Engineer | NCB | NC WG2A |
| M Blythe | Area Electrical Engineer, North Derby | NCB | WG2B, 2C, 2D |
| G Cooper | Area Electrical Engineer, South Notts | NCB | WG2B, 2C |
| H M Harrison | Mechanical/Electrical Inspector | NUM | NC SC1 |
| T A Hughes | Deputy Chief Electrical Engineer | NCB | WG2A, 2B, 2C, 2E DP |
| E Loynes | Representative | AMEME | NC SC1 WG2B |
| S Luxmore | HM Principal Electrical Inspector | HMI M & Q | NC WG2A, 2E |
| H A W Pettinger | Director | Otis | SC1 WG2E |
| H Routledge | HM Senior Electrical Inspector | HMI M & Q | WG2B, 2D |
| A Rushton | Representative | BACM | NC SC3 WG2E |
| W Walker | Section Engineer | GEC | WG1B, 2A, 2B, 2C |
| R F Young (Secretary) | HM District Inspector | HMI M & Q | NC SC1, 3, 4, WG2D, 2E, 4C(E) |
## Sub-committee 3 (SC3) – Maintenance

<table>
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<th>Organisation</th>
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<tbody>
<tr>
<td>L Walker (Chairman)</td>
<td>Director of Plant and Workshops</td>
<td>NCB</td>
<td>NC</td>
</tr>
<tr>
<td>A Bulmer</td>
<td>Mining Engineer</td>
<td>NUM</td>
<td>WG3B, 3C, 3D</td>
</tr>
<tr>
<td>B Hill</td>
<td>HM Deputy Principal Electrical Inspector</td>
<td>HMI M &amp; Q</td>
<td>WG4C(E)</td>
</tr>
<tr>
<td>J Dunn</td>
<td>Senior Engineer (Selby Project), North Yorks</td>
<td>NCB</td>
<td>WG3A</td>
</tr>
<tr>
<td>D H Jackson</td>
<td>Area Maintenance Engineer and Plant Pool Manager, North Derby</td>
<td>NCB</td>
<td>WG3A, 3C</td>
</tr>
<tr>
<td>A Rushton</td>
<td>Representative</td>
<td>BACM</td>
<td>NC SC2 WG2E</td>
</tr>
<tr>
<td>R A Smith</td>
<td>Deputy Chief Engineer (Maintenance and NCB Engineering Services)</td>
<td>WG1B, 3A, 3B, 3C, 3D</td>
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</tr>
<tr>
<td>W G Stephenson</td>
<td>HM Senior Inspector of Mechanical Engineering</td>
<td>HMI M &amp; Q</td>
<td>SC4, DP</td>
</tr>
<tr>
<td>R F Young (Secretary)</td>
<td>HM District Inspector</td>
<td>HMI M &amp; Q</td>
<td>NC SC1, 2, 4, WG2D, 2E, 4C(E)</td>
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</table>

## Sub-committee 4 (SC4) – Metallurgy and Materials

<table>
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<th>Member</th>
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<th>Organisation</th>
<th>Other Committees</th>
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<tbody>
<tr>
<td>J N L Woodley (Chairman)</td>
<td>Deputy Director (Project Development)</td>
<td>MRDE</td>
<td>NC</td>
</tr>
<tr>
<td>J Foley</td>
<td>Principal Scientific Officer</td>
<td>SMRE</td>
<td>WG4A</td>
</tr>
<tr>
<td>E H Hands</td>
<td>Joint Managing Director</td>
<td>Blacks</td>
<td>SC1 WG1A</td>
</tr>
<tr>
<td>L C James</td>
<td>Head of Technical Services Division</td>
<td>MRDE</td>
<td>SC1 WG1A, 4B</td>
</tr>
<tr>
<td>H D Munson</td>
<td>Senior Principal Scientific Officer</td>
<td>SMRE</td>
<td>NC SC1</td>
</tr>
<tr>
<td>K Saunders</td>
<td>Mining Engineer</td>
<td>NUM</td>
<td></td>
</tr>
<tr>
<td>W G Stephenson</td>
<td>HM Senior Inspector of Mechanical Engineering</td>
<td>HMI M &amp; Q</td>
<td>SC3, DP</td>
</tr>
<tr>
<td>D A Sutcliffe</td>
<td>Head of Metallurgy and Materials Branch</td>
<td>MRDE</td>
<td>WG4A</td>
</tr>
<tr>
<td>V M Thomas</td>
<td>Deputy Director (Electrical Engineering)</td>
<td>MRDE</td>
<td>WG4C, 4C(E)</td>
</tr>
<tr>
<td>T L Wall</td>
<td>Principal Scientific Officer</td>
<td>SMRE</td>
<td>WG1A, 4B</td>
</tr>
<tr>
<td>R F Young</td>
<td>HM District Inspector</td>
<td>HMI M &amp; Q</td>
<td>NC SC1, 2, 3, WG2D, 2E, 4C(E)</td>
</tr>
</tbody>
</table>

## Working Group 1A (WG1A)

<table>
<thead>
<tr>
<th>Member</th>
<th>Official Designation</th>
<th>Organisation</th>
<th>Other Committees</th>
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</thead>
<tbody>
<tr>
<td>E H Hands (Chairman)</td>
<td>Joint Managing Director</td>
<td>Blacks</td>
<td></td>
</tr>
<tr>
<td>D R Allin</td>
<td>Mechanical Engineer, HQ Shafts and Winding Section</td>
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<tr>
<td>V M Thomas (Chairman)</td>
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<td>R A Smith</td>
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**Working Group 4C(E) (WG4C(E))**

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**Drafting panel**

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<td>Head of Shafts and Winding Section</td>
<td>NCB</td>
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1 See page 74 for List of Abbreviations
2 NC denotes National Committee; SC Sub-committee; WG Working Group; DP Drafting panel
3 Mr Clanzy replaced Mr Blelloch when the latter became Chairman of the National Committee on 31 March 1974
4 Mr Starr died on the 18 November 1974
5 Mr Cooper replaced Mr D Stewart when the latter retired from Area Chief Engineer, South Durham area, NCB, on 31 March 1974
6 Mr Stephenson replaced Mr Starr
7 Mr Saunders died on 18 November 1974
8 Mr Hands replaced Mr Blelloch when the latter became Chairman of the National Committee on 31 March 1974
9 On 1 November 1974 Working Group 4C was enlarged and re-named Working Group 4C(E)
### List of Abbreviations

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<tr>
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<tr>
<td>AMEME</td>
<td>Association of Mining Electrical and Mechanical Engineers</td>
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<td>GEC</td>
<td>GEC Electrical Projects Ltd</td>
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<td>HMI M &amp; Q</td>
<td>HM Inspectorate of Mines and Quarries, Health and Safety Executive</td>
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<td>MRDE</td>
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<td>SMRE</td>
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<td>Westinghouse</td>
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PART 1B

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Philosophy of braking

1 Design guide description and reserve factor concept

1 In Part 1A, paragraphs 4, 13(5), 14 and 111.4, reference is made to a proposed design guide for winding engine brake gear components. A review of the design of winding engine components suggests that such a guide would help to promote a common approach to the design process. To obtain data for a design guide, strain gauge measurements were made on brake components of a number of existing winding engines. These measurements, together with information from other examinations of winding engines, indicated additional areas where further guidance on design is desirable. Brake design will be the subject of the first such design guide.

Resolution of forces

2 In general the strain gauging results showed that the steady state loads in components were in reasonable agreement with those which would be predicted by known methods of resolution of forces. However, it was clear that more than one method is in use; and having obtained the basic forces there should be little variation in the techniques adopted for considering the effective loads in particular portions of components. The design guide will, therefore, contain a chapter on resolution of forces with the objective that this will come into common usage and hence facilitate direct comparison of calculations by various users and manufacturers.

Design based on fatigue considerations

3 The straight gauge results also established that, for certain components, fluctuating loads were present and evidence from the non-destructive testing of winding engines showed that some components, particularly screwed components, were cracked. It is, therefore, necessary to establish methods of stress analysis based on fatigue considerations. A considerable portion of the guide is devoted to this topic. Explanations and definitions are given, the method of interpretation is based on the Goodman diagram and several worked examples are included.

Stress considerations

4 It was further established from the examinations that winding engine components are not always well designed in respect of stress concentrations. Examples of good and bad design relative to stress concentrations will be given and preferred designs shown which can minimise or obviate the effect of stress concentrations. A sufficient number of charts of stress concentration factors applicable to the cases that may occur in the various winding engine components will also be included.

Additional design considerations

5 The guide also draws attention to further aspects of design. Examples are:

(1) Where similar or duplicated components share theoretically the applied braking load. The design of each should be such that, in the event of one failing, the other has ample margin to withstand the most adverse resultant load.
(2) Where components are subject to a combination of effects. For a component such as a horizontal brake operating rod, design should account for additional stresses due to self weight, the maximum anticipated friction between pins and pin bearing surfaces, and the effects of eccentricity. Guidance on allowances for these effects will be included in the guide.

(3) The importance of designing so that maintenance is not unnecessarily inhibited. This applies particularly to components with a service life dependent upon adequate lubrication.

(4) The requirement for simplicity of design, compatible with the duty. Where possible design should be of such a nature and geometry, with suitable means of adjustment provided, that loads and load sharing can be predicted with confidence.

**Design of welded components**

6 The guide will consider the design of welded components, and the fatigue aspects of welding will be dealt with as well as good design features for welded joints.

**Materials**

7 Guidance will be given on materials which would normally conform to British Standard and should have proven mechanical properties.

**Abnormal loads**

8 The design of components used for applying the brake in an emergency should be given particular consideration because of additional loads that can result. Account should also be taken of the number of times the emergency brake is applied during routine testing and proving.

**Definitions**

9 Various terms will be defined in the guide to reduce misunderstandings and to establish a common terminology. Though definitions are set out in other reference books, the guide will give its own definitions, eg of normal stress, maximum stress, minimum stress, mean stress, stress amplitude, stress range, fatigue limit, to prevent misunderstandings, wording will be simplified to avoid misinterpretation. In calculations the concept of Reserve Factor as opposed to the more traditional Factor of Safety will be introduced and defined in an unambiguous manner. In view of its importance, an explanation of the Reserve Factor concept is in subsequent paragraphs.

**Safety margins in components of winding engines**

10 Knowledge of the strength of engineering components and of their service conditions can never be complete, nor can human error be eliminated in design, manufacture or use. Hence the designed capability of a component must always exceed the most severe service condition expected. A safety margin is often expressed in the form of a statistic Factor of Safety in UK statutory regulations and in manufacturing and purchasing specifications in the UK mining industry. It may be defined as the ratio of the nominal ultimate static strength of a component for a specified service condition, to the normal maximum static service load for the same condition. Minimum static Factor of Safety values assigned to important mining components have become established by experience, published data, and by profiting from early failures. Values now range from 6.5 to 15.
11. This traditional practice has been reviewed because the accident at Markham Colliery resulted directly from a brake component fatigue failure, and the Markham Official Report recommended that:

   a design analysis be made of all winding engine brake components essential for safety to ensure that the working stresses can be sustained and to establish definitive life. This analysis should take account of the fluctuations of stresses irrespective of the conventional static factors of safety. The use of screwed components should be avoided wherever possible.

12. A difficulty with the conventional Factor of Safety concept lies in differing manners in which it is used. It can be used in its simplest form as the ratio of nominal ultimate static strength to the normal maximum static service load. Parameters can be incorporated to take account of stress fluctuations, stress concentrations, shock loading etc, but such parameters may be based on general experience rather than quantified by calculation or measurement for the component under consideration.

13. It can therefore be misleading to assume that a large Factor of Safety necessarily results in a large reserve of strength without knowing the precise basis on which it has been determined. Many parameters, which vary with design and operation, must be considered before safety margins against failure from modes such as static, fatigue and impulsive loading, can be specified in practice. Table 1.1 shows, in check list form, parameters relevant to the design, manufacture and installation of components of winding engines. Determination of safety margins is only practicable if:

   (1) The parameters to be considered are clearly defined.

   (2) Design data is available for those parameters which can be quantified.

   (3) Allowances are made for those parameters which cannot be quantified; these allowances should be fully correlated with past successful practice and design methods, to establish confidence and continuity of experience.

14. Although the Factor of Safety concept has served the industry well, progress towards a common and disciplined method of design which quantified as many of the operational parameters as possible would be beneficial to safety. While such an approach is possible within the present conventional Factor of Safety concept, its extension could be made more difficult by previous understandings and practice. It is therefore proposed that the concept of a Reserved Factor should be progressively introduced and staff instructed in its use.

**Reserve factor**

15. For a component to be safe, the strength of its materials should always exceed the maximum service stress calculated when all parameters have been considered. It is proposed to express this reserve of strength in the form of a ratio called a Reserve Factor. Table 1.1a lists parameters for assessing material strength appropriate to expected service conditions. Table 1.1b lists parameters for assessing maximum service stress including parameters for assessing maximum service stress including parameters which cannot usually be quantified but for which allowances should be made. Data sources appropriate to parameters in table 1.1 are also shown.

16. For components of mine winding systems, Reserve Factor would be defined as follows:
A Reserve Factor for a component is the ratio of the failure stress or stress range, depending upon possible modes of failure, to the corresponding maximum service stress or stress range.

17 It may be prudent to choose values for the Reserve Factor related to the risk potential and consequences of failure. For winding engines, values appropriate to each application will be recommended in the design guide and these will also be related to past practice wherever possible to ensure continuity of experience. It is intended that the design guide will provide or refer to data on the parameters used in determining Reserve Factor in a form suitable for application in a design office and when checking the integrity of existing installations.

Summary

18 (1) To rationalise safety margins, the traditional Factor of Safety concept should be critically examined where it is employed in design, manufacturing and user practice for mine winding equipment. It should initially be supplemented, and as experience is gained replaced, by a Reserve Factor concept in which all parameters affecting failure are quantitatively assessed, or allowances made for them, using data sources such as those shown in table 1.1. Non-determinate parameters should be reduced to a minimum.

(2) When designing components for new equipment or replacements for existing equipment, quantified parameters, particularly those arrived at by calculation or test, and allowances for parameters which cannot be quantified should be clearly defined, together with the value assigned to the Reserve Factor so that a reserve of strength is provided against inaccuracy.

(3) The proposed design guide will tabulate both Factor of Safety and Reserve Factor values for selected examples of critical components of winding equipment to ensure continuity of experience and understanding of the Reserve Factor concept.

Table 1.1 – Check list of design parameters

<table>
<thead>
<tr>
<th>Parameters and detail</th>
<th>Data sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material properties</td>
<td></td>
</tr>
<tr>
<td>Ultimate strength (tensile/ compressive)</td>
<td>Material specifications</td>
</tr>
<tr>
<td>Proof or yield strength</td>
<td></td>
</tr>
<tr>
<td>Elastic limit</td>
<td></td>
</tr>
<tr>
<td>Elastic modulus</td>
<td></td>
</tr>
<tr>
<td>Fatigue strength (Goodman diagram)</td>
<td>Design guide</td>
</tr>
<tr>
<td>Notch toughness (at service temperatures)</td>
<td>Material specifications or tests</td>
</tr>
<tr>
<td>Weld strength</td>
<td></td>
</tr>
<tr>
<td>Hardenability</td>
<td></td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th><strong>Type and frequency of loading</strong></th>
<th>Static tensile/bending/shear/combined loads</th>
<th>Purchasing specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Static compressive (buckling)</td>
<td>Design guide</td>
</tr>
<tr>
<td></td>
<td>Fluctuating or reversing (direct/bending)</td>
<td></td>
</tr>
<tr>
<td>Rate of application (eg shock)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| **Specified service life and load duty** | Purchasing specifications |

### 1.1b Assessing maximum service stress

<table>
<thead>
<tr>
<th><strong>Primary static load conditions</strong></th>
<th>Dead loads</th>
<th>Purchasing specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Specified payloads</td>
<td>Design guide</td>
</tr>
<tr>
<td></td>
<td>Overload protection devices</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Dynamic loads</strong></th>
<th>Oscillations/resonance</th>
<th>Test data from existing installations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Frictional variations</td>
<td>Design guide</td>
</tr>
<tr>
<td></td>
<td>Inertia/shock loading</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Secondary loads (examples)</strong></th>
<th>Self weight</th>
<th>Design calculations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Eccentricity</td>
<td>Design guide</td>
</tr>
<tr>
<td></td>
<td>Bearing friction</td>
<td></td>
</tr>
</tbody>
</table>

| **Occasional loads** | Arising in testing or unusual duties | Purchasing specifications |

<table>
<thead>
<tr>
<th><strong>Load sharing between components</strong></th>
<th>Installation and manufacturing tolerances</th>
<th>Purchasing specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Wear/specified malfunctions of other components</td>
<td>Design calculations</td>
</tr>
<tr>
<td></td>
<td>Service adjustments</td>
<td>Design guide</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Stress concentrations</strong></th>
<th>Notches or radii</th>
<th>Makers’ drawings</th>
</tr>
</thead>
<tbody>
<tr>
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<td>Threads</td>
<td>Design guide</td>
</tr>
<tr>
<td></td>
<td>Section changes</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Surface finish/defects</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Manufacturing tolerances and wear</strong></th>
<th>On cross sections</th>
<th>Standards Makers’ drawings</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>On fits and clearances</td>
<td>Purchasing specifications</td>
</tr>
<tr>
<td></td>
<td>On joint strength</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Parameters which cannot usually be quantified and for which allowance should be made</strong></th>
<th>Corrosion</th>
<th>Design guide</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Accidental damage/overload</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Standard of manufacture</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Residual stresses</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Standard of maintenance</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Loss of strength due to fretting</td>
<td></td>
</tr>
</tbody>
</table>
2 Compounding of electrical and mechanical braking systems

1 Numerous references are made in Part 1A of the Report, particularly in paragraph 7, to the effects of compounding of electrical and mechanical braking systems and consideration was given to this effect on various types of electrical winding engines.

2 Compounding can be defined as the summation of the mechanical braking torque and the electrical torque irrespective of whether the electrical torque is assisting or opposing. The resulting effective braking torque will depend upon the electrical control scheme employed. Where the electrical torque assists the mechanical braking torque, then, depending upon the ratio between the dynamic and static components of the moving parts of the winding system, unacceptably high retardation rates could be produced. Conversely if the electrical torque opposes the mechanical brake (as normally occurs on electric winding engines with closed-loop control systems) then unacceptably low rates of retardation could be produced.

Effect of compounding on various types of winding engines

DC winding engines using a closed-loop system of control

3 Control systems of this type would normally preclude any significant increase in braking torque but could cause a serious reduction in braking torque. It is thus necessary to remove electrical braking when the mechanical brake is proved on.

DC winding engines using open-loop systems of electrical control but having servo assistance

4 Control systems of this type would preclude any significant increase in braking torque but, as with DC closed-loop systems, they could cause a serious reduction in braking torque. Such a control scheme has the additional disadvantage that the current in the DC loop may reach the pre-set tripping value. It is thus necessary to remove electrical braking when the mechanical brake is proved on.

AC winding engines using a closed-loop speed control system

5 Control systems of this type while precluding any significant increase in braking torque could cause a serious reduction in braking torque. It is thus necessary to remove electrical braking when the mechanical brake is proved on.

AC winding engines using a closed-loop torque control system

6 In this type of control system electrical torque would assist the mechanical braking torque and could produce unacceptably high rates of retardation. It is thus necessary to remove electrical braking when the mechanical brake is proved on.

AC winding engines using an open-loop control system but fitted with dynamic braking

7 If dynamic braking is automatically applied, then, as power is not available to the motor, electrical torque must assist mechanical braking torque. The degree of assistance will depend upon the type of electrical control scheme employed.

General

8 It will be necessary to examine individual winding engines to decide the necessity of removing electrical braking when the mechanical brake is proved on. The effects of the rates of retardation at the drum where electrical braking assists the mechanical brake are set out in tables 2.1 and 2.2.

9 The figures in the tables are based on the characteristics of typical winding systems and, if the braking torque produced by the electrical system were equal to
that produced by the mechanical brake, the total would be 200% braking force. This is an extreme case; normally, electrical braking force would be about one half of mechanical braking force. The figures in table 2.1 are for winding systems with a balance rope and those in table 2.2, for systems without a balance rope.

Table 2.1 – Single parallel drum system

2.1a With balance rope (Imperial Units)

<table>
<thead>
<tr>
<th>Depth and speed</th>
<th>Braking force (ton)</th>
<th>Retardation (ft/sec²)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>BF 100%</td>
<td>BF 200%</td>
</tr>
<tr>
<td></td>
<td>Min</td>
<td>Ave</td>
</tr>
<tr>
<td>Winding depth 3000 ft</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manwinding speed 30 ft/sec</td>
<td>2 5 18 Ave 132 36</td>
<td>72 7.6 10 16.3 18.8</td>
</tr>
<tr>
<td>1½ 6 15 Ave 105 29.6 59.2 8.2 10 17.2 19.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 1 9 Ave 65 19.2 38.4 9.0 10 18.5 19.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Max 86 25.7 51.4 9.3 10 18.9 19.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Winding depth 2000 ft</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manwinding speed 30 ft/sec</td>
<td>2 6 18 Ave 118 30.6 61.2 6.7 10 15.1 18.4</td>
<td></td>
</tr>
<tr>
<td>1½ 4 15 Ave 99 26.7 53.4 7.4 10 16.1 18.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 1.5 9 Ave 64 18.4 36.8 8.5 10 17.7 19.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Max 86 25.2 50.4 8.9 10 18.3 19.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Winding depth 1000 ft</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manwinding speed 30 ft/sec</td>
<td>2 7 18 Ave 97 32.2 64.4 8.4 13 19.0 23.7</td>
<td></td>
</tr>
<tr>
<td>1½ 4.5 15 Ave 79 24.9 49.8 8.3 12 18.5 22.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 2 9 Ave 55 15.1 30.2 7.7 10 16.5 18.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Max 75 21.3 42.6 8.3 10 17.4 19.1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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### 2.1b With balance rope (Metric Units)

<table>
<thead>
<tr>
<th>Diam (mm)</th>
<th>Diam (m)</th>
<th>(tonne)</th>
<th>(tonne)</th>
<th>(m/sec²)</th>
<th>(m/sec²)</th>
<th>(m/sec²)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Winding depth 915 m</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manwinding speed</td>
<td>9.15 m/sec</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>51</td>
<td>5.1</td>
<td>5.5</td>
<td>Ave 134</td>
<td>36.5</td>
<td>73.2</td>
<td>2.3</td>
</tr>
<tr>
<td>Max 160</td>
<td>44.8</td>
<td>89.6</td>
<td>2.4</td>
<td>3.0</td>
<td>5.2</td>
<td></td>
</tr>
<tr>
<td>Min 85</td>
<td>23.5</td>
<td>46.9</td>
<td>2.3</td>
<td>3.0</td>
<td>5.2</td>
<td></td>
</tr>
<tr>
<td>45</td>
<td>3.0</td>
<td>46</td>
<td>Ave 106</td>
<td>30.1</td>
<td>60.1</td>
<td>2.5</td>
</tr>
<tr>
<td>Max 131</td>
<td>37.7</td>
<td>75.4</td>
<td>2.6</td>
<td>3.0</td>
<td>5.4</td>
<td></td>
</tr>
<tr>
<td>Min 48.6</td>
<td>14.1</td>
<td>28.2</td>
<td>2.7</td>
<td>3.0</td>
<td>5.5</td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>1.0</td>
<td>2.7</td>
<td>Ave 66</td>
<td>19.5</td>
<td>39</td>
<td>2.7</td>
</tr>
<tr>
<td>Max 87</td>
<td>26.1</td>
<td>52.2</td>
<td>2.8</td>
<td>3.0</td>
<td>5.8</td>
<td></td>
</tr>
</tbody>
</table>

| **Winding depth 610 m** |          |         |         |          |          |          |
| Manwinding speed | 9.15 m/sec |          |         |          |          |          |
| 51 | 6.1 | 5.5 | Ave 120 | 31.1 | 62.6 | 2.0 | 3.0 | 4.6 |
| Max 145 | 39 | 78 | 2.2 | 3.0 | 4.8 |
| Min 79 | 0.5 | 41 | 2.0 | 3.0 | 4.6 |
| 45 | 4.1 | 4.6 | Ave 101 | 27.1 | 54.3 | 2.3 | 3.0 | 4.9 |
| Max 125 | 39.9 | 69.5 | 2.4 | 3.0 | 5.2 |
| Min 47.6 | 13.3 | 26.6 | 2.4 | 3.0 | 5.2 |
| 26 | 1.5 | 2.7 | Ave 65 | 18.7 | 37.4 | 2.6 | 3.0 | 5.4 |
| Max 87 | 25.9 | 51.2 | 2.7 | 3.0 | 5.6 |

| **Winding depth 305 m** |          |         |         |          |          |          |
| Manwinding speed | 9.15 m/sec |          |         |          |          |          |
| 51 | 7.1 | 5.5 | Ave 98 | 32.7 | 65.4 | 2.6 | 4.0 | 5.8 |
| Max 123 | 38.7 | 77.4 | 2.5 | 3.7 | 5.6 |
| Min 61.6 | 20.4 | 40.8 | 2.5 | 4.0 | 5.8 |
| 45 | 4.6 | 4.6 | Ave 80 | 25.3 | 50.6 | 2.5 | 3.7 | 5.6 |
| Max 103 | 30.8 | 61.6 | 2.5 | 3.4 | 5.4 |
| Min 40.6 | 11.9 | 23.8 | 2.4 | 3.0 | 5.2 |
| 26 | 2.0 | 2.7 | Ave 55.8 | 15.3 | 30.7 | 2.3 | 3.0 |
| Max 76 | 21.6 | 43.3 | 2.5 | 3.0 | 5.0 |

### 2.2a Without balance rope (Imperial Units)

<table>
<thead>
<tr>
<th>Depth and speed</th>
<th>Rope Dia (in)</th>
<th>Man Load (ton)</th>
<th>Drum Dia (ft)</th>
<th>System inertia (ton)</th>
<th>Braking force (ton)</th>
<th>Retardation (ft/sec²)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Winding depth 3000 ft</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>BF 100%</td>
<td>BF 200%</td>
</tr>
<tr>
<td>Manwinding speed</td>
<td>30 ft/sec</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>5</td>
<td>18</td>
<td>Ave 122</td>
<td>42.3</td>
<td>84.6</td>
<td>8.1</td>
</tr>
<tr>
<td>Max 148</td>
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<td>100.4</td>
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<td>29.9</td>
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<tr>
<td>Min 78</td>
<td>26.8</td>
<td>53.6</td>
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<td>14.0</td>
<td>19.2</td>
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<td>1¼</td>
<td>3</td>
<td>15</td>
<td>Ave 99</td>
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<td>63.2</td>
<td>8.0</td>
</tr>
<tr>
<td>Max 123</td>
<td>36.8</td>
<td>73.6</td>
<td>7.8</td>
<td>11.5</td>
<td>17.4</td>
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</tr>
<tr>
<td>Min 46</td>
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<td>25.2</td>
<td>7.2</td>
<td>10.5</td>
<td>16.0</td>
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<td>9</td>
<td>Ave 63</td>
<td>17.2</td>
<td>34.4</td>
<td>7.6</td>
</tr>
<tr>
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<td>17.3</td>
<td>19.1</td>
</tr>
<tr>
<td>Depth and speed</td>
<td>Manwinding speed 30 ft/sec</td>
<td>Depth and speed</td>
<td>Manwinding speed 30 ft/sec</td>
<td></td>
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<td>----------------</td>
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<tr>
<td>Winding depth 2000 ft</td>
<td>2 6 18</td>
<td>Min 92</td>
<td>35.4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ave 113</td>
<td>40.9</td>
<td></td>
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<td></td>
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<td></td>
<td>Max 139</td>
<td>48</td>
<td></td>
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</tr>
<tr>
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<td>Min 75</td>
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<td></td>
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<td></td>
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<tr>
<td></td>
<td>1½ 4 15</td>
<td>Ave 95</td>
<td>32.1</td>
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<td>39.7</td>
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<tr>
<td></td>
<td>Min 46</td>
<td>13.6</td>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td>1 1½ 9</td>
<td>Ave 63</td>
<td>17.6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Max 84</td>
<td>23.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Winding depth 1000 ft</td>
<td>2 7 18</td>
<td>Min 74</td>
<td>26.3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ave 94</td>
<td>36.3</td>
<td></td>
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<td></td>
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<tr>
<td></td>
<td>Max 117</td>
<td>44.1</td>
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<td>Min 59</td>
<td>22.6</td>
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<tr>
<td></td>
<td>1½ 4.5 15</td>
<td>Ave 77</td>
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<tr>
<td></td>
<td>Max 100</td>
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<td></td>
<td>Min 39</td>
<td>14.0</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>1 2 9</td>
<td>Ave 54</td>
<td>17.5</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Max 74</td>
<td>22.3</td>
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2.2b Without balance rope (Metric Units)

<table>
<thead>
<tr>
<th>Dia (mm)</th>
<th>Dia (m)</th>
<th>Dia (tonne)</th>
<th>Dia (tonne)</th>
<th>Dia (m/sec^2)</th>
<th>Dia (m/sec^2)</th>
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<tbody>
<tr>
<td>Winding depth 915 m</td>
<td>Manwinding speed 9.15 m/sec</td>
<td>Min 101.6</td>
<td>38.5</td>
<td>77</td>
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<tr>
<td></td>
<td>Ave 124</td>
<td>43</td>
<td>86</td>
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<td>51</td>
<td>102</td>
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<td></td>
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<td>Ave 100.6</td>
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<td>Max 125</td>
<td>37.4</td>
<td>74.8</td>
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<td>26</td>
<td>1.0</td>
<td>2.7</td>
<td>Ave 64</td>
<td>17.5</td>
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<tr>
<td></td>
<td>Max 85.3</td>
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<td>Diam (m)</td>
<td>(tonne)</td>
<td>(tonne)</td>
<td>(m/sec²)</td>
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<td>---------</td>
<td>----------</td>
</tr>
<tr>
<td>Manwinding speed 9.15/sec</td>
<td>51</td>
<td>7.1</td>
<td>5.5</td>
<td>2.1</td>
<td>4.9</td>
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<tr>
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This is a web-friendly version of Safe manriding in mines: First Report of the National Committee for Safety of Manriding in shafts and Unwalkable Outlets, originally produced by HM Inspectorate of Mines.
Means of implementing philosophy of braking

3 Strain gauge investigations of winding engine brake gear

1 In part 1A, paragraph 11, reference is made to a strain gauge exercise made jointly by the Mining Research and Development Establishment (MRDE) and the Safety in Mines Research Establishment (SMRE) on the brake components of four winding engines representative of the main types in service.

2 The aims of the investigation were:

(1) To determine stress levels in components under operational conditions and to compare the measured values with those obtained by traditional static methods of calculating nominal forces and stresses.

(2) To ascertain the nature and magnitude of stresses not allowed for by traditional methods of calculation so that improved design criteria can be established for winding engine brake components.

3 In general, emphasis was placed on measuring these stresses in single line and critical components. A single line component is defined as a critical component the failure of which to function as designed renders a system totally inoperative. The failure of such a component may cause immediate danger to men. A critical component is defined as one, the failure of which will result in the loss of at least 50% of braking area or force.

4 This section gives an outline of the results of investigations made on the brake components of the four winding engines.

Types of winding engine

The four types of winding engine selected for investigation were:

- Pye Hill No 2 – Dead weight system.
- Daw Mill No 1 – Spring-applied system.
- Barrow No 1 – Fluid power applied system.
- Langwith No 1 – Thruster type, spring-applied system.

Schematic diagrams of the brake gear showing the strain gauged components are in figs 3.1 to 3.4.

6 The Pye Hill and Barrow brake gears (figs 3.1 and 3.3) are multi-linkage systems with components at either end of the drum coupled to a cross shaft having a centrally mounted lever through which the brakes are operated. At Pye Hill, normal operation of the brakes is by dead weights which are raised to release the brakes by a low-pressure hydraulic brake engine. These brakes are used only for parking as the winding cycle is controlled manually through the electrical system. At Barrow, the brakes are operated by a low pressure hydraulic brake
engine with dead weights taking over in the event of a failure of the hydraulic supply. Electrical braking is available. Both the Pye Hill and Barrow brake systems contain a number of single line and critical components.

7 The Daw Mill brake gear (fig 3.2) consists of two independent pairs of caliper brake assemblies connected only by a common oil supply. The brakes are spring applied and hydraulically released. The winding cycle is controlled automatically through the electrical system and the caliper brakes are manually applied to the drum only when it is stationary or when creeping during decking operations. No single line component is contained in the mechanical brake assembly but there are a number of critical components.

8 The Langwith brake gear (fig 3.4) consists of four brake thruster units which are independent except for a common oil supply. The shoe of each unit is applied by spring force and released by oil pressure. Electrical braking is available. No single line or critical component is contained in the mechanical brake assembly.

Strain investigations and results

9 Strain gauges of electrical resistance foil type were bonded to components of the braking systems as shown in figures 3.1 to 3.4; the positions of the gauges being chosen for accessibility and uniformity of cross-section. Signals from the gauges were fed, via conditioning modules, to tape recorders or oscillographs. The gauges were connected via bridge networks, and calibration of the systems enabled the outputs from the bridges to be recorded as stress analogues. Where possible individual gauges in a bridge were interconnected to enable either the direct or bending stresses to be measures on a section of a component. The terminology used for the stresses discussed in this section is given below.

(1) PRIMARY STRESS. Stress resulting from the force which the component is primarily designed to withstand; eg in a tie rod the direct tensile stress; or, in a lever the bending stress.

(2) SECONDARY STRESS. Stress caused by self weight, bending, eccentricity etc. Secondary stresses are not necessarily lower than primary stresses.

(3) DYNAMIC STRESS. Stress produced because of rapid movement and arrest of brake linkages during operation of the brake. Dynamic stresses are transient and may be several times greater than primary stresses. They are considered to be a form of secondary stress.

10 The stress datum for the tests was taken to be the brake off condition. At a later date, where possible, components were disconnected from the brake systems to determine if assembly stresses were present. The assembly stresses which proved to be significant were: (a) a direct stress of 0.9 tonf/in² (14 MN/m²) caused by the spring force measured in a spring rod at Daw Mill Colliery (b) a direct stress of 1.8 tonf/in² (28 MN/m²) and a bending stress of 2.2 tonf/in² (34 MN/m²) in a bridge bolt at Langwith (c) at Daw Mill Colliery a bending stress of 1.5 tonf/in² (23 MN/m²) in the top tie rod due to its deadweight and (d) a direct stress of 0.7 tonf/in² (11 MN/m²) caused by the deadweight measured in the full section of the weight rod at Pye Hill Colliery. It was not possible to arrange for either the bridge piece at Langwith Colliery or any of the brake posts/calipers at the other collieries to be in a zero stress condition.

11 At Langwith Colliery there was no convenient position for attaching strain gauges to the holding-down bolts of the brake thrusters unit. To enable the distribution of stresses in the bolts to be investigated, a separate series of tests
was made on a brake unit in a laboratory. Braking forces were simulated statically by hydraulic rams.

Figure 3.1 Diagrammatic arrangement of deadweight applied fluid power released winding engine break at Pye Hill No2

Figure 3.2 Diagrammatic arrangement of spring applied high pressure fluid power at Daw Mill No1
Figure 3.3 Diagrammatic arrangement of fluid power applied, fluid power released winding engine break at Barrow No2

Figure 3.4 Diagrammatic arrangement of spring applied, fluid power released winding engine unit brake at Langwith No1

12 At the collieries, stresses inducted in the brake gear were recorded when brakes were applied manually with drums stationary and during normal winding cycles. Simulated emergency brake applications were made with the drums stationary and when rotating at maximum winding speeds. The effects of empty and loaded cages were investigated, and stresses induced in the brake posts/callipers during the brake holding tests were recorded.

13 Normal winding cycles at Daw Mill and Pye Hill Collieries were controlled through the electrical systems until the drums were stationary before the
mechanical brakes were applied. However, at Barrow and Langwith Collieries the drums were brought to rest by the mechanical brakes after electrical power had been cut off.

14 Investigations were made at Daw Mill, Pye Hill and Barrow Collieries with the setting of the brake systems altered to simulate worn and unadjusted brakes. This was achieved by adjusting the tie rods to increase the clearances between the brake paths and linings from the normal 1/16 in (1.6 mm) to 5/16 in (7.9 mm). Additional tests were made at Barrow Colliery to determine stresses induced by conditions which simulated a fracture of a hydraulic supply pipe and caused the emergency deadweight to fail.

15 Fluctuations of stress, and stress changes from datum to the steady state conditions during various brake applications were tabulated and conclusions deduced from these. Figs 3.5 and 3.6 are comparisons of typical records obtained from the gauges on the weight rod at Pye Hill and the tie rod at Daw Mill for normal and emergency brake applications.

Figure 3.5 Comparisons of typical test records of weight and rod stresses at Pye Hill colliery

Conclusions

16 Under normal operating conditions forces in the brake components of each type of winding engine calculated from measured primary stress, show satisfactory agreement with those calculated by traditional methods used for winding engines.

17 In addition to the primary stresses which the components are designed to withstand, secondary stresses of varying magnitude were produced in the components. The secondary stresses were caused by bending forces or transient conditions.

18 Measurement of secondary bending stresses which are due to self weight, pin friction or eccentricity etc, showed that they can be of similar magnitude to the primary stresses. At Daw Mill, for example, a bending stress of 1.5 tonf/in²
(23 MN/m$^2$) was measured near the centre of one of the tie rods while the primary stress change was 1.9 tonf/in$^2$ (29 MN/m$^2$).

Figure 3.6 Comparisons of typical test records of top and rod stresses at Daw Mill colliery

19 During normal winding operations where electrical braking was not used, transient stresses up to three times the magnitude of the primary stresses were produced.

20 Emergency braking produced transient secondary stresses in mechanical brake components of all the winding engines and magnitudes of over three times the primary stresses were recorded.

21 Unequal distributions of forces in multi-linkage systems and secondary stresses should be taken into account when designing brake gear. In the multi-linkage brake systems at Pye Hill and Barrow Collieries, the braking effort was found to be divided approximately in the proportions of 40% and 60% between the two brake paths.

22 Stress and force profiles must be determined from the strain gauge results to enable conditions at critical sections to be established. Critical stress points are generally at sharp changes of section or in threaded portions where strain gauges cannot be fixed. In addition there were problems of accessibility for positioning gauges on the brake assemblies.

23 From records obtained with both directions of drum rotation or differing loads in the cages, no regular pattern of results emerged for any of the braking systems. Fast and slow emergency applications of the brake at Barrow produced changes of stress in the brake gear of similar magnitude.

24 Dynamic stresses of an impulsive nature, approximately nine times the calculated primary stress, were produced in the weight rod at Pye Hill when the weight fell. This only occurred during emergency braking and the normal precautions had been taken by the attachment of a cradle to support the weight in the event of failure of the weight rod.

25 At Pye Hill and Daw Mill, when the setting of linkages was altered to create excessive clearance at each brake path, the stress changes in all the components were no higher than when the brakes were normally adjusted.
26. With excessive clearance at each brake path at Barrow, only about 80% of the normal breaking effort was available at the two brake paths although the input as determined from gauges on the lever arm remained unchanged. It is probable that this effect was because of changes in geometry of the brake system due to additional movement.

27. When the linkage on one brake path at Pye Hill was backed off to give zero force change on brake application, the primary force change in the other side increased by approximately 75% rather than 100%. Thus about 87% of the total braking force was available from one side only while the input force determined from gauges on the lever arm remained unchanged. The secondary stresses increased almost in direct proportion to the alteration in primary forces.

28. Although the conditions which simulated a broken oil pipe at Barrow were not as severe as anticipated, the magnitude of the dynamic stresses produced in the slotted links was up to four times that of the normal primary stresses. In addition dynamic stresses produced in the level and lay shaft were higher than in any of the other tests, but these stresses were dissipated by inertia, resilience or clearance effects before reaching the brake shoes.

29. Initial tests made on holding down bolts at Langwith Colliery indicated that the installed bolt load was approximately 10 tonf (100 kN). Subsequent laboratory tests made on a brake unit using this value of installed load showed that, during simulated brake applications, the highest change in axial stress was produced in the front pair of bolts and the unit tended to pivot about the centre pair of bolts. Bending stress changes were also produced in the bolts and these stress changes together with the axial stress changes increased as the installed bolt load was decreased. For example with the bolts tightened to a load of 10 tonf (100 kN), equivalent to an axial stress of 5.1 tonf/in\(^2\) (79 MN/m\(^2\)), the application of brakes produced an axial stress of 1.3 tonf/in\(^2\) (20 MN/m\(^2\)), and a bending stress change of 0.7 tonf/in\(^2\) (11 MN/m\(^2\)) whereas with a bolt load of 6 tonf/in\(^2\) (80 kN), equivalent to an axial stress of 3.1 tonf/in\(^2\) (65 MN/m\(^2\)), the corresponding stress changes were 1.9 tonf/in\(^2\) (29 MN/m\(^2\)) and 1.1 tonf/in\(^2\) (17 MN/m\(^2\)). If the stress changes become too large fatigue failure of the bolts could occur. Calculation of the bolt stress is complex and worthy of further study.

30. The stress changes during brake application were lower in the components of the Langwith brake unit than in any of the brake components of the other winding engines. Even during emergency braking the maximum stress change never exceeded 0.6 tonf/in\(^2\) (9 MN/m\(^2\)). These low stresses confirm the conclusion (Part 1A, paragraph 13.7) that linkages should be as simple as possible.

4 Recommended materials for winding engine brakes

In Part 1A paragraphs 17 and 20.1, reference is made to materials suitable for use in the construction of winding engine brake gear. These materials are listed below and a column of rationalised choices is included to limit the types of steel which need to be used. The En classification of steels in BS 970: 1965 has been abandoned by the British Standards Institution. However, for convenience, the old En references are in brackets where appropriate.
### Material

<table>
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<tr>
<th>Component</th>
<th>General</th>
<th>Rationalised</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Brake paths</strong></td>
<td>Brake paths can be made either by casting or by forming steel plate. It is recommended that all new brake paths should be made from castings but replacement brake paths may be either cast or formed.</td>
<td></td>
</tr>
<tr>
<td>CASTINGS</td>
<td>Fine-grained pearlitic grey cast iron to either Grade 14 or 17 of BS 1452: 1961. Control of the graphite flake size by an inoculation process is recommended. FORMED PLATE, 080M40 (En 8) of BS 970: Part 1: 1972. The plate should have a minimum hardness of 152 Brinell.</td>
<td></td>
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<tr>
<td><strong>Brake linings</strong></td>
<td>The linings, which should be asbestos-based, should be compatible with the brake path material and the specification should be supplied by the manufacturer for approval.</td>
<td></td>
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<tr>
<td><strong>Brake shoes</strong></td>
<td>Grade 43A of BS 4360: 1972.</td>
<td></td>
</tr>
<tr>
<td><strong>Brake posts</strong></td>
<td>Grade 43A of BS 4360: 1972, in sectional fabrication.</td>
<td></td>
</tr>
<tr>
<td><strong>Anchor brackets</strong></td>
<td>These may be either cast or fabricated.</td>
<td></td>
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<tr>
<td>CAST. Grade A of BS 1456: 1967 or Grade A of BS 592: 1967 (Specified Izod). (Both of these specifications are incorporated in BS 3100: 1967).</td>
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<td><strong>Brake shaft pedestals</strong></td>
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<tr>
<td><strong>Brake shafts</strong></td>
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<td><strong>Brake levers</strong></td>
<td>These may be either fabricated or forged.</td>
<td></td>
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<tr>
<td>FABRICATED. Grades 43C, 43D, 50C, 50D of BS 4360: 1972 in the normalised condition.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FORGED. Grade 150M19 (En 14A) of BS 970: Part 1: 1972 in the normalised or P condition (fine grain controlled).</td>
<td></td>
<td>Grade 150M19</td>
</tr>
<tr>
<td><strong>Spring rods and tie rods inc turn buckles, rod ends etc</strong></td>
<td>Grades 43C, 43D, 50C, 50D of BS 4360: 1972 in the normalised condition or Grade 150M19 (En 14A) of BS 970: Part 1: 1972 in the normalised condition (fine grain controlled).</td>
<td>Grade 150M19</td>
</tr>
<tr>
<td><strong>Pins</strong></td>
<td>Materials to be as for Spring Rods etc. For applications where size considerations preclude the use of these materials (ie where geometric factors are limiting) the higher strength material to be used should be the subject of agreement. Due consideration should be given to the avoidance of seizure by the selection of suitable materials or by the use of bushes.</td>
<td></td>
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<td><strong>Bell cranks or triangular levers</strong></td>
<td>Grade 43A of BS 4360: 1972.</td>
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<td><strong>Springs</strong></td>
<td>Grade 250A58 (En 45A) or 735A50 (En 47) of BS 970: Part 5: 1972.</td>
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<tr>
<td><strong>Thruster brake spring case, side plates and bridge reaction plates</strong></td>
<td>Grade 43A of BS 4360: 1972.</td>
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5 Routine non-destructive testing (NDT) of winding engine brake gear and associated equipment

Introduction

1 In Part 1A, paragraphs 18, 19 and 20.3, 118(1) reference is made to the necessity for routine non-destructive testing of winding engine brake gear and associated equipment. Suitable methods are discussed in this section. Non-destructive testing of winding engine components other than brake gear is discussed in section 31. Visual and magnetic particle inspection (MPI) supported by ultrasonic and dye-penetrant testing is recommended. The procedure is to be adopted for the routine inspection of installed winding engine brake equipment. It may also be adopted, where applicable, by manufacturers of new equipment who are required to employ a sufficient level of inspection using non-destructive testing during manufacture to ensure that finished components satisfy the standards of this procedure. Particular attention is drawn to the more stringent requirements for threaded regions and welds on new components compared with existing ones.
Items to be inspected

2 (1) All components which transmit force from brake springs, fluid or weights to braking surfaces.

   (2) All components of drives to automatic contrivance and depth indicator unless monitored.

Frequency of examination

3 (1) For the purpose of deciding frequency of examination of the component, it is necessary to classify each winding engine installation according to its duty, based on the number of winds per year and whether the winding engine is at a principal or subsidiary shaft. The following divisions are made: heavy duty, more than 200 000 winds/year; medium duty, 10 000 to 200 000 winds/year; light duty less than 10 000 winds/year. A wind is any single journey in a shaft.

   (2) It is further necessary to consider each component in a braking system and to classify it as either critical or non-critical. From a consideration of the significance of failure it is possible to identify critical components which may be defined as those components the failure of any one of which will result in the loss of at least 50 per cent of braking area or force. For the purpose of non-destructive testing three classifications of components are made namely:

   (A) single line components;

   (B) other critical components as defined above.

   (C) non-critical components the failure of any one of which will result in loss of less than 50% of braking area or force.

However, where historical evidence in respect of failure or design indicates, a component classified under (B) may be subjected to the requirements of classification (A).

(3) The frequencies of examination are as follows:

<table>
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<th>Duty of Installation</th>
<th>Critical components</th>
<th>Non-critical components</th>
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<td>Classification (A)</td>
<td>Classification (B)</td>
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<tr>
<td>Heavy</td>
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<tr>
<td>Light</td>
<td>3 to 5</td>
<td>7 to 10</td>
</tr>
</tbody>
</table>

(4) The non-critical classification (C) components require less frequent examination but it is recommended that a visual examination of these components is made at the time when full non-destructive tests are made on components in classification (B).

(5) An example of the breakdown of a typical winding engine brake into the various component classifications (A), (B) or (C) is in appendix 5.1.
(6) Any change in duty of a winding engine will necessitate reassessment of its
duty and possible reclassification for the purpose of NDT.

Precautions to be taken during testing

4 The mine engineering staff should be responsible for ensuring that brake
equipment is available for examination, and for dismantling and reassembling work
as well as for general security and safety during inspection. To ensure the latter, the
winding engine drum should be positively secured against movement in a manner
independent of the brake, and the winding engine isolated from the power supply
prior to commencement of any work on the system, due consideration being given
to any ancillary equipment. The person(s) testing should indicate when he has
completed his task so that the winding engine can be restored for duty.

Preparation

5 (1) Those components for which all surfaces to be examined can be exposed
should be inspected by the preferred method of magnetic particle
inspection (MPI), the areas to be examined being described under
Procedure. Components which cannot have their surfaces exposed shall
be examined in situ using ultrasonics. It will be necessary on a local basis
for a responsible engineer to build up a schedule of components to be
removed and those to be tested in situ (see appendix 5.2).

(2) In the case of threaded components the full threaded length must be
exposed for examination.

(3) The components to be tested by magnetic particle techniques should have
all oil, grease, dirt, and where necessary, paint removed, and the surface to
be inspected rendered as clean as practicable.

(4) The areas to be tested should be given a thin coat of quick drying white
background paint. However, for machined surfaces on close fitting
components other paints may be more suitable where ease of removal of
the paint is important.

(5) Particular care should be taken with examination of the threaded areas of
any component to ensure that accumulated material at the thread root is
removed and that background paint does not collect in thread roots to
form local thick deposits.

(6) Components to be tested by ultrasonic techniques should have both ends
accessible wherever possible and the ends of the component should be
cleaned and all paint removed. In the case of bolts, and other components
with domed ends, the ends of the component should be machined flat
normal to the axis.

Procedure

6 Visual examination of wear, corrosion and surface damage should be made by
the engineering staff in conjunction with the metallurgist or testing engineer.
Measurement of pins etc, and maintenance of engineering standards should be the
responsibility of the engineering staff. NDT examinations should be carried out by
operators who have demonstrated their competence in the particular method. For
magnetic particle inspection, mineral oil-based black ink complying with BS 4069:
1966 should be applied preferably by spraying during magnetisation.
**Rods, links, pins (components with the length/diameter ratio normally greater than 5/1)**

*Visual*

7 1. Complete access to the component to be examined is required and, where necessary to ensure this, the component should be completely removed from the system.

2. All surfaces should be examined visually for evidence of wear, corrosion, and/or surface damage.

3. The diameters of pins and associated female components should be measured, the sizes recorded and compared with either the designer’s or manufacturer’s tolerances.

*Magnetic particle inspection*

8 1. **LONGITUDINAL DEFECTS.** All the surface should be examined by MPI and the current flow method employing alternating current used for the detection of longitudinal defects. The recommended current is 100 amp per inch (25.4 mm) of probe distance, applied for approximately 5 seconds, the number of applications being sufficient to ensure adequate magnetisation. To avoid arcing and excessive sparking the current must not be switched on until the probes are firmly in contact with the component and the probes must not be removed until the current has been switched off. Probes should not be applied to threaded parts of components.

2. **TRANSVERSE DEFECTS.** A longitudinal magnetic flux method should be used for detection of transverse defects employing coil magnetisation, yoke (electro-magnetic) magnetisation or a permanent magnet. If appropriate a current flow method may be used. Magnetic flux indicators should be used to establish that sufficient field strength is available for each size and type of component for all the longitudinal magnetic flux methods.

**Components with variable length/diameter ratios**

1 **CLEVISES, LEVERS AND BARS**

*Visual*

9 1. All clevises, levers, and bars, other than brake shaft levers which will be examined in situ, should be removed from the system.

2. All surfaces should be visually examined for evidence of wear, corrosion and surface damage.

3. All holes should be measured, the sizes recorded and compared with either the designer’s or manufacturer’s sizes and tolerances.

*Magnetic particle inspection*

10 1. All surfaces should normally be examined by MPI.

2. The current flow method using alternating current will normally be used for these components and the conditions detailed above concerning
magnetisation will apply. This method may be supplemented by half-wave rectified AC should the need arise.

(3) On some components the use of yoke (electromagnetic) magnetisation or permanent magnets may be more suitable, in which case magnetic flux indicators must be used to ensure adequate field strength.

(4) Depending on the shape of the component it may be necessary to magnetise in directions approximately at right angles to the first test.

2 BELL CRANKS, ANCHOR BRACKETS, BRAKE POSTS AND BRAKE SHOES

Visual

11 (1) All components should be sufficiently dismantled to expose surfaces to be examined.

(2) Surfaces of the components should be examined visually and the method of manufacture ascertained, eg welded, cast riveted etc.

(3) Sizes of pin holes should be measured, recorded and compared with either the designer's or manufacturer's sizes and tolerances.

(4) Section changes in castings and welds on fabricated components should be closely examined for evidence of manufacturing defects.

(5) Surfaces of holes should be examined for evidence of corrosion, pick up and surface damage.

Magnetic particle inspection

12 Areas which should be examined are set out below.

13 BELL CRANKS:

(1) the areas extending up to 3 in (75 mm) around holes and bosses on all types;

(2) boss welds on fabricated bell cranks.

14 ANCHOR BRACKETS:

(1) the area extending up to 3 in (75 mm) around holes and bosses on all types;

(2) regions of section change in cast brackets;

(3) welds on fabricated brackets.

15 BRAKE POSTS:

(1) the areas extending up to 3 in (75 mm) around holes and bosses on all types;

(2) riveted areas on posts;

(3) welds within 12 in (300 mm) of holes in fabricated posts.
BRAKE SHOES:

(1) the areas extending up to 3 in (75 mm) around holes and bosses on all types;

(2) welds within 12 in (300 mm) of holes in fabricated shoes.

(3) region of section change (if any) within 12 in (300 mm) of holes in case shoes.

17 Procedures should comply with the requirements of paragraphs (10(2), 10(3) and 10(4) of this section.

Springs

Visual

18 (1) Springs should be removed from the system whenever possible.

(2) Surfaces should be examined for evidence of wear, corrosion and surface damage.

Magnetic particle inspection

19 (1) All surfaces should normally be examined by MPI.

(2) The current flow method with probes should not be used for crack detection of springs.

(3) The use of a central conductor is the most suitable method of magnetisation for transverse defects in springs, although yoke magnetisation or permanent magnets may give satisfactory results.

(4) Whichever method of magnetisation is used, flux indicators should be employed to establish that adequate field strength is available.

Brake shafts, pins and bolts in situ

Visual

20 (1) Normally it will not be possible to carry out visual examinations of these components other than of a very limited nature.

(2) Keys and keyways in brake shafts should be visually examined for evidence of damage.

Ultrasonic examination

21 (1) Note comments in paragraph 5(6) above.

(2) If it is decided to examine the main brake shaft in situ, the shaft should be subjected to ultrasonic inspection. This should be supplemented where possible by MPI. In some instances it may be necessary to examine pins and bolts in situ, eg when the component would be damaged during dismantling.

(3) If possible a drawing of the component should be obtained. Failing this, as detailed a drawing as can be made from measurements of the component should be prepared for the operator before testing is undertaken, for comparison with the echo pattern.
(4) Any dirt, loose paint, scale or rust should be removed from end faces of the component.

(5) Selection of probe frequency will depend on characteristics of the material of the component, but the frequency should be as high as possible consistent with adequate penetration without undue attenuation.

(6) Longitudinal or compression wave problems with a zero angle of incidents of the entrant energy beam will generally be found adequate. The use of angled probes may be necessary on some components.

(7) Separate or combined transmitter and receiver probes are equally suitable.

(8) Acoustic coupling media should be confined to suitable oils or greases to avoid contamination of bearing lubricants.

(9) The whole face of both ends of the component should be scanned wherever possible. On some installations this may necessitate the use of special probes owing to close proximity of ends of the component to the winding installation structure.

(10) The echo pattern obtained should be correlated with echoes to be expected by virtue of the component geometry. This should preferably be done during the actual examination, and an instrument with a calibrated delay suitable for the purposes will enable greater accuracy to be achieved.

(11) A record of echo patterns obtained should be made, together with details of the testing technique including sensitivity of the instrument so that these can be referred to during subsequent examinations, and any deviations noted.

**Drives to automatic contrivance and depth indicator (gears, shafts, couplings, joints and universal joints)**

**Visual**

22 (1) All surfaces should be visually examined for evidence of wear, corrosion and surface damage.

**Non-destructive testing**

**Ferromagnetic gears**

23 (1) All teeth, keyway corners and webs in castings should be examined.

(2) Gears of the normal sizes encountered have small tooth lengths and are therefore generally unsuitable for examination by current flow methods.

(3) Ferromagnetic gears should be examined using yoke (electromagnetic) magnetisation, permanent magnets as described under paragraph 10(3) above, or current flow methods when applicable. All gears should be demagnetised after testing, except when AC current flow is used.

**Non-ferromagnetic gears**

24 (1) Areas to be examined to be as in paragraph 23(1) above.
(2) Non-ferromagnetic gears should be examined using dye-penetrant methods.

(3) Dye-penetrant testing should comply with the requirements of BS 4124: Part 3: 1968.

**Shafts**

25 (1) Regions of section change and any areas observed to be damaged should be examined.

(2) A longitudinal flux method should be used as described in paragraph 8(2) above.

**Couplings and joints**

All surfaces should be examined by MPI as described in paragraph 10 above.

**Universal joints**

26 Universal joints of the Hardy Spicer type as opposed to the clevis type would be damaged during stripping for examination, therefore no action is recommended.

**Sundry components**

27 (1) Nuts should be visually examined for evidence of wear, corrosion and other adverse features. A longitudinal magnetic flux method should be used as described in paragraph 8(2) above for detection of imperfections in nuts, the nuts to be examined in two directions at right angles to each other. When coil magnetisation is used extenders may be necessary to ensure that sufficient field strength is available. Current flow methods may be used for large nuts greater than 6 in (150 mm).

(2) Internally threaded components such as turn buckles should be examined visually for evidence of wear, corrosion and surface damage. All surfaces should be examined by MPI using the method described in paragraph 8(1) above. Ultrasonic examinations as described in paragraph 21 above may be used to detect transverse imperfections in internal threads.

**General considerations**

28 It is possible that in some brake gear, components manufactured in wrought iron will be revealed by the use of MPI, eg by detection of inclusions and the presence of fire welding. It is essential to be on the look out for any unusual materials or methods of manufacture that are not covered by this Section so that a suitable ruling can be made by the responsible engineer in conjunction with a metallurgist.

**Personnel and method of reporting**

29 (1) Notes concerning the qualifications of suitable operators for conducting NDT procedures are given in appendix 5.3.

(2) The responsible mine engineer should be notified of the condition of any doubtful components before the person carrying out the examination leaves the site so that appropriate decisions can be made as to the necessity and urgency of replacement.
(3) A written report should be submitted within fourteen days of carrying out the examination.

(4) The written report should identify each component tested, the method of testing, and the position and extent of any imperfections.

**Interpretation of results**

**Visual examination**

30 WEAR. For components in which a certain amount of wear has been observed it will be necessary to refer to wear limits defined at the time of design of the component. In the absence of specified wear limits, these should be established. If wear exceeds the acceptable limit the component should be rejected.

31 CORROSION. It is difficult to lay down any criteria for rejection owing to corrosion because of wide variation in this type of deterioration that might be observed. General corrosion is usually less harmful than localised pitting and may be acceptable if light. However, when pitting corrosion has occurred this should be referred to a competent metallurgist for an opinion. In any event efforts should be made to identify the source of corrosion.

32 SURFACE DAMAGE. Components, particularly pins, showing surface break up and severe scuffing should be replaced. Efforts should be made to find out the cause of damage. Particular attention must be given to the condition of mating parts especially where the mating part is a bearing with small angular movement, and to those situations where fretting may occur. Any such damage found on a winding engine brake system should be treated as a serious defect and dealt with accordingly.

**MPI dye-penetrant and ultrasonic testing**

33 Appendix 5.4 contains guidelines for suggested action following NDT of the wide range of components found in winding engine brakes. These should facilitate a unified approach to the question of acceptance or rejection; however, where it is difficult to make a decision reference should be made to a competent metallurgist for an opinion. Where a component is designated for replacement urgency should be decided by the responsible engineer in consultation with the metallurgist, who should take into consideration such factors as the type and size of component, the position and extent of the imperfection. Where it is necessary to carry out welding to repair a component the procedure to be adopted should be agreed with the metallurgist.

**APPENDIX 5.1 Example of classification of components**

The components shown in figs 5.1 and 5.2 may be classified as follows:

**Critical classification (A)**

*Single line on brake system: none.*

*Components which have shown incipient failure: none.*

*Design considerations: items 146 and 147 (low safety factors from calculations).*

*Single line in indicator and controller drives: items 200 to 207/4.*
### Critical classification (B)

**Items, failure of which results in loss of 50% of effective brake surface area or force**

<table>
<thead>
<tr>
<th>Items</th>
<th>Numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brackets</td>
<td>102 to 105</td>
</tr>
<tr>
<td>Pins</td>
<td>136 and 137</td>
</tr>
<tr>
<td>Crossheads</td>
<td>142 and 143</td>
</tr>
<tr>
<td>Pins</td>
<td>144 and 145</td>
</tr>
<tr>
<td>Clevis</td>
<td>148 and 149</td>
</tr>
<tr>
<td>Clevis pin</td>
<td>150 and 151</td>
</tr>
<tr>
<td>Brake shoes</td>
<td>152 to 155</td>
</tr>
<tr>
<td>Pivot shafts</td>
<td>156 to 159</td>
</tr>
<tr>
<td>Anchor brackets</td>
<td>160 to 163</td>
</tr>
</tbody>
</table>

### Non-critical classification (C)

**Items, failure of which results in loss of 50% of effective brake surface area or force**

<table>
<thead>
<tr>
<th>Items</th>
<th>Numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brackets</td>
<td>102 to 105</td>
</tr>
<tr>
<td>Cylinders</td>
<td>106 to 109</td>
</tr>
<tr>
<td>Shafts</td>
<td>110 to 117</td>
</tr>
<tr>
<td>Brackets</td>
<td>118 to 121</td>
</tr>
<tr>
<td>Springs</td>
<td>122/1 to 12</td>
</tr>
<tr>
<td>Brackets</td>
<td>124 to 127</td>
</tr>
<tr>
<td>Rods</td>
<td>128/1 to 131/1</td>
</tr>
<tr>
<td>Clevises</td>
<td>132 to 135</td>
</tr>
<tr>
<td>Turnbuckles</td>
<td>128/2 to 131/2</td>
</tr>
<tr>
<td>Rods</td>
<td>128 to 131</td>
</tr>
<tr>
<td>Clevises</td>
<td>132 to 135</td>
</tr>
<tr>
<td>Clevis pins</td>
<td>148 and 149</td>
</tr>
<tr>
<td>Bell cranks</td>
<td>138 to 141</td>
</tr>
<tr>
<td>Rods</td>
<td>128 to 131</td>
</tr>
<tr>
<td>Clevises</td>
<td>148 and 149</td>
</tr>
<tr>
<td>Clevis pins</td>
<td>150 and 151</td>
</tr>
<tr>
<td>Brake rods</td>
<td>146 and 147</td>
</tr>
<tr>
<td>Clevises</td>
<td>148 and 149</td>
</tr>
<tr>
<td>Clevis pins</td>
<td>150 and 151</td>
</tr>
<tr>
<td>Brakes shoes</td>
<td>152 to 155</td>
</tr>
<tr>
<td>Pivot shafts</td>
<td>156 to 159</td>
</tr>
<tr>
<td>Shafts and</td>
<td>207 to 207/4</td>
</tr>
<tr>
<td>couplings</td>
<td></td>
</tr>
</tbody>
</table>

### APPENDIX 5.2 Schedule of items to be removed for testing and of items to be tested in situ

The schedule has been drawn up for the Brake Gear shown in figures 5.1 and 5.2.

#### Items to be removed for inspection

<table>
<thead>
<tr>
<th>Items</th>
<th>Numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pivot pins</td>
<td>100 and 101</td>
</tr>
<tr>
<td>Brackets</td>
<td>102 to 105</td>
</tr>
<tr>
<td>Cylinders</td>
<td>106 to 109</td>
</tr>
<tr>
<td>Shafts</td>
<td>110 to 117</td>
</tr>
<tr>
<td>Brackets</td>
<td>118 to 121</td>
</tr>
<tr>
<td>Springs</td>
<td>122/1 to 12</td>
</tr>
<tr>
<td>Brackets</td>
<td>124 to 127</td>
</tr>
<tr>
<td>Rods</td>
<td>128/1 to 131/1</td>
</tr>
<tr>
<td>Turnbuckles</td>
<td>128/2 to 131/2</td>
</tr>
<tr>
<td>Rods</td>
<td>128 to 131</td>
</tr>
<tr>
<td>Clevises</td>
<td>132 to 135</td>
</tr>
<tr>
<td>Pins</td>
<td>136 to 137</td>
</tr>
<tr>
<td>Bell cranks</td>
<td>138 to 141</td>
</tr>
<tr>
<td>Crossheads</td>
<td>142 and 143</td>
</tr>
<tr>
<td>Pins</td>
<td>144 and 145</td>
</tr>
<tr>
<td>Brake rods</td>
<td>146 and 147</td>
</tr>
<tr>
<td>Clevises</td>
<td>148 and 149</td>
</tr>
<tr>
<td>Clevis pins</td>
<td>150 and 151</td>
</tr>
<tr>
<td>Brakes shoes</td>
<td>152 to 155</td>
</tr>
<tr>
<td>Pivot shafts</td>
<td>156 to 159</td>
</tr>
<tr>
<td>Shafts and</td>
<td>207 to 207/4</td>
</tr>
<tr>
<td>couplings</td>
<td></td>
</tr>
</tbody>
</table>

#### Items to be tested in situ

<table>
<thead>
<tr>
<th>Items</th>
<th>Numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anchor brackets</td>
<td>160 to 163</td>
</tr>
<tr>
<td>Holding down bolts</td>
<td>170/1 to 8 and 171/ to 8</td>
</tr>
<tr>
<td>Foundations bolts</td>
<td>172/1 to 6 and 173/1 to 6</td>
</tr>
<tr>
<td>Gearwheels</td>
<td>200 to 204</td>
</tr>
<tr>
<td>Bevel gears</td>
<td>205 to 206</td>
</tr>
</tbody>
</table>
Figure 5.1 Typical elevation on winding engine brake gear

Figure 5.2 Typical plan on winding engine indicator and control gear
APPENDIX 5.3 Qualifications for NDT operators

1 NDT has many pitfalls for the unwary and the unskilled and it is essential that examinations are carried out by capable operators. The operator should preferably have a background of mechanical and/or mining engineering and he should fully appreciate the implications and value of NDT. He should have had adequate training at a suitable and accepted authority such as the School of Applied Non-Destructive Testing or West Bromwich College of Commerce and Technology, and have received a certificate of proficiency in magnetic particle inspection, penetrant testing and ultrasonic techniques.

2 Allied to the training he should have wide experience in applying these techniques and should be fully conversant with the various types of equipment to be examined. He should be able to compile clear and concise reports on his findings and it is desirable that he should be capable of working in close collaboration with other personnel and able to advise and assist where necessary.

3 Above all he should be a man of technical integrity, because a negative result from an NDT test only indicates that nothing has been found and the more conscientious and able the operator the greater the chance that nothing found equals nothing present.

APPENDIX 5.4 Guidelines to suggested action following NDT

<table>
<thead>
<tr>
<th>Component</th>
<th>Observation</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brake posts</td>
<td>Service induced cracks in welds.</td>
<td>Grind out and re-weld if necessary.</td>
</tr>
<tr>
<td></td>
<td>Manufacturing stop-start cracks in welds.</td>
<td>New Gear grind out and re-weld</td>
</tr>
<tr>
<td></td>
<td>Radial cracks from holes in bosses</td>
<td>Remove boss and replace.</td>
</tr>
<tr>
<td></td>
<td>Imperfection in boss material</td>
<td>Assess depth and reject if necessary.</td>
</tr>
<tr>
<td></td>
<td>Transverse imperfections.</td>
<td>Reject.</td>
</tr>
<tr>
<td>Brake shoes</td>
<td>Radial cracks from holes in bosses.</td>
<td>Remove boss and replace.</td>
</tr>
<tr>
<td></td>
<td>Imperfection in boss material</td>
<td>Assess depth and reject if necessary.</td>
</tr>
<tr>
<td></td>
<td>Transverse imperfections.</td>
<td>Reject.</td>
</tr>
<tr>
<td></td>
<td>Cast shoes, hot tears in section change.</td>
<td>Ground out and repair weld if necessary.</td>
</tr>
<tr>
<td></td>
<td>Fabricated shoes, imperfections in weld (particular care where bosses are in welded addenda to structures).</td>
<td>Repair weld as necessary.</td>
</tr>
<tr>
<td></td>
<td>Service induced cracks.</td>
<td>Reject.</td>
</tr>
<tr>
<td>Springs</td>
<td>Transverse imperfections.</td>
<td>Reject.</td>
</tr>
<tr>
<td></td>
<td>Obvious longitudinal imperfections.</td>
<td>Reject.</td>
</tr>
<tr>
<td>Brake shafts</td>
<td>Indications from ultrasonic examination.</td>
<td>Strip down and examine using magnetic particle inspection and treat as bars.</td>
</tr>
</tbody>
</table>
### Component | Observation | Action
--- | --- | ---
All components | Component made from wrought iron. Component containing fire welds. | Phase replacement. Replace. |
Nuts | All imperfections. | Reject if outside permissible limits given in fig 5.3. |
Forgings | Service induced cracks. Longitudinal imperfections down centre of bar subsequently bumped up to form eye – these can propagate at 45° giving a near transverse defect. All manufacturing imperfections. | Reject. Reject. (a) Attempt to grind out. (b) If unsuccessful and cannot replace with similar forging it is preferable to redesign component for fabrication by welding or threading. |

![PIN and NUT](image)

**Figure 5.3 Pin and nut**

<table>
<thead>
<tr>
<th>Part</th>
<th>Type of imperfection</th>
<th>Permissible imperfections</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Shaded areas</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pin, barrel and thread</td>
<td>Transverse</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>Longitudinal</td>
<td>None &gt; 1 ¼”</td>
</tr>
<tr>
<td><strong>Unshaded areas</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pin head and nut</td>
<td>Transverse</td>
<td>None &gt; 3/8”</td>
</tr>
<tr>
<td></td>
<td>Longitudinal</td>
<td>None &gt; 3/8”</td>
</tr>
</tbody>
</table>
Figure 5.4 Fork link

<table>
<thead>
<tr>
<th>Part</th>
<th>Type of imperfection</th>
<th>Permissible imperfections</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Shaded areas</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surfaces</td>
<td>Transverse</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>Longitudinal</td>
<td>None &gt; 3/8”</td>
</tr>
<tr>
<td>Holes and edges</td>
<td>Transverse</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>Longitudinal</td>
<td>None &gt; 5/8”</td>
</tr>
<tr>
<td><strong>Unshaded areas</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Body and edges</td>
<td>Transverse</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>Longitudinal</td>
<td>None &gt; 1 1/4”</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Component</th>
<th>Observation</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bars and rods</td>
<td>Transverse imperfections in threads.</td>
<td>Reject.</td>
</tr>
</tbody>
</table>

- Transverse manufacturing imperfections in unthreaded areas. Attempt to grind out, but not deeper than thread depth.
- Transverse fatigue cracks. Reject.
- Longitudinal imperfections running into thread. New Gear reject.
- Longitudinal imperfections within 2 inches (51 mm) of the thread. Existing Gear reject where deeper than half thread depth.
- Longitudinal imperfections away from thread. Existing Gear reject if deeper than thread root.
- Explore depth by instruments and grinding, reject if deeper than thread root.
<table>
<thead>
<tr>
<th>Component</th>
<th>Observation</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Some have forged ends which will present problems as to whether imperfections longitudinal or transverse.</td>
<td>Use same criteria as given in fig 5.4 to decide direction of imperfection. Treat as for forgings.</td>
<td></td>
</tr>
<tr>
<td>Pins</td>
<td>Transverse imperfections.</td>
<td>Reject</td>
</tr>
<tr>
<td></td>
<td>Longitudinal imperfections.</td>
<td>Reject if outside permissible limits given in fig 5.3.</td>
</tr>
<tr>
<td></td>
<td>Longitudinal imperfections associated with surface break-up, severe scuffing and wear.</td>
<td>Reject</td>
</tr>
<tr>
<td>Pins in situ</td>
<td>Indications from ultrasonic examination.</td>
<td>Strip down and examine using magnetic particle inspection and treat as pins.</td>
</tr>
<tr>
<td>Clevises</td>
<td>Transverse and longitudinal imperfections.</td>
<td>Reject if outside permissible limits given in fig 5.4.</td>
</tr>
<tr>
<td>Bell cranks</td>
<td>Service induced cracks around bosses and welds.</td>
<td>Grind out and re-weld if necessary.</td>
</tr>
<tr>
<td></td>
<td>Manufacturing stop-start cracks at welds.</td>
<td>New Gear grind out and re-weld.</td>
</tr>
<tr>
<td>Anchor brackets</td>
<td>Castings: hot tears.</td>
<td>Grind out and repair weld if necessary.</td>
</tr>
<tr>
<td></td>
<td>Castings: service induced cracks.</td>
<td>Reject</td>
</tr>
<tr>
<td></td>
<td>Fabricated:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(a) service induced cracks in welds.</td>
<td>Grind out and re-weld if necessary.</td>
</tr>
<tr>
<td></td>
<td>(b) manufacturing stop-start cracks at welds.</td>
<td>New Gear grind out and re-weld.</td>
</tr>
<tr>
<td></td>
<td>Existing Gear generally leave, but might be ground out and re-welded.</td>
<td></td>
</tr>
<tr>
<td>Internally threaded components</td>
<td>Longitudinal imperfections on threads.</td>
<td>Reject where deeper than half thread depth.</td>
</tr>
<tr>
<td></td>
<td>Indications of transverse nature from visual and ultrasonic.</td>
<td>If in doubt reject.</td>
</tr>
</tbody>
</table>

6 Guidelines on ferrous materials for fabricated winding engine brake equipment

1 In Part 1A reference is made in paragraphs 18 and 19 to the necessity for fabricated brake parts to be manufactured to a satisfactory standard to ensure reliability in service. This will require quality control to confirm that the recommended materials are used, inspection at all stages of fabrication to ensure that agreed welding procedures are observed, and final inspection including non-destructive testing to confirm that manufactured components satisfy the requirements outlined in section 5. However, it is not intended that this section should provide a code of practice or detailed welding instructions, but rather that it should contain some basic guidelines. It is recommended that in the manufacture of these important fabricated items some form of quality assurance is adopted. Details of a manufacturer’s practice and procedures should be agreed prior to commencement of production.
2 The following guidelines should be observed:

(1) All material of construction should be supplied with a certificate confirming compliance with the appropriate specification.

(2) Plate should be ultrasonically tested to C3 of DD21: 1972*. Quality grading of steel plate from 12 mm to 150 mm thick by means of ultrasonic testing, particular attention being given to the areas to be welded.

(3) After flame cutting the edges should be made smooth.

(4) Welding should be in accordance with BS 5135: 1974 Metal-arc welding of carbon and carbon manganese steels, which specifically itemises:
   (a) selection of welding consumables;
   (b) approval testing of operators;
   (c) design of welds including joint gaps.

(5) The welding process should be such that the hardness in the as welded deposit and heat affected zone should not exceed 350 Vickers.

(6) Where it is necessary to join plates to achieve the full size of the components required, full thickness welds should be used; the integrity of these welds should be checked using an appropriate non-destructive testing technique.

(7) All fabrications should be stress relieved at a temperature within the range 580° to 620°C.

(8) On completion of welding and stress relief, a thorough visual inspection should be carried out. This should be aided by magnetic particle inspection of all visible welds and free edges.

7 Guidelines on castings for winding engine brake equipment

In part 1A, paragraph 19, cast materials have been recommended for some of the components, notably brake paths and low pressure brake engine parts. In other instances a choice of material is given so that the component may be either cast or fabricated. To ensure that all cast brake parts are manufactured to a satisfactory standard and to guarantee reliability in service, the following basic requirements should be observed:

(1) The casting should be designed for the application and this requires full liaison between the design engineer and the foundry.

(2) The material should conform to the general and special requirements of the relevant British Standard.

(3) There should be adequate control during manufacture to ensure that the material conforms to the chemical analysis and meets the mechanical properties required. Test certificates giving details of these should be supplied.

* British Standard for development
(4) In order to confirm the soundness of the casting non-destructive testing (e.g., radiographic, ultrasonic and/or magnetic particle inspection) should be used during inspection. The level of testing should be such as to ensure that castings satisfy the requirements outlined in section 5 and other acceptance criteria as agreed between purchaser and manufacturer. The tests and criteria should be specified in the order.

(5) When selecting a foundry for the production of castings, due attention should be given to the standing of the foundry, and to the types of components and materials in which the foundry has specialised.

8 Winding engine mechanical brakes

GENERAL REQUIREMENTS FOR NEW MECHANICAL BRAKES

1 In Part 1A, paragraph 21, reference is made to the general requirements for new winding engine mechanical brakes, the objectives of which are to:

(1) Ensure safety under any component failure condition or malfunction.

(2) Provide brake performance matched to service and emergency requirements.

(3) Emphasis the need for design and construction of the brake to be as simple as possible.

(4) Ensure that system pressure failure will cause application of the brake.

(5) Ensure that the design incorporates the features necessary to enable tests to be readily and safely carried out as outlined in the Model Code for the Testing of Drum Winding Engines (section 32) and any other user requirements.

2 The following broad requirements should not inhibit the use of new or different techniques and materials where evaluation shows that existing safety standard will be maintained or improved upon.

Brake duty

3 The brakes should provide the braking torques required by the Coal and Other Mines (Shafts, Outlets and Roads) Regulations 1960, or any superseding regulations in force, produce specified maximum and minimum retardations and cater for any other specified duties of the winding engine, e.g., rope capping, rope changing, winding abnormal loads, level changing on clutched drum winding engines (refer to appendix 8.1). The retardation of a drum winding engine conveyance should not exceed 1 g in order to minimise risk of injury to persons following application of the brake after an emergency trip. To achieve this, in practical terms, retardation of the drum should not exceed 16 ft/sec² (4.9 m/sec²) and should preferably be less than 12ft/sec² (3.7 m/sec²). Maximum retardations for friction winding engines are specified by regulations which are at present being reviewed.

Retention of braking torque following component failure

4 In the event of failure or malfunction of any one component of any one system, the mechanical brake system should provide sufficient braking torque to bring the winding system safely to rest, based on the expected variation of brake lining characteristics in service, and produce not less than 50% of the normal braking force. Appendix 8.2 gives alternative methods of achieving this requirement. Serious
reduction of mechanical braking torque may also occur as a result of contamination of brake paths or lining by oil, moisture or other matter. It is anticipated that in most cases the effect of such contamination would not be greater than the effect of failure of a brake component and thus the effect of contamination would be within the 50%, allowance for loss of braking force owing to failure of a component.

5 In this context, to bring the winding system safely to rest means preventing the descending conveyance from passing the lowest landing at a speed greater than that which the pit bottom arresting devices can accept to bring the conveyance to rest at a specified rate. It also means ensuring that the ascending conveyance does not strike the headframe and that the detached capel is not wound into the winding engine house.

**Brake operating system**

6 The brakes should act directly on paths or discs integral with the drum, and the brake operating system should be so designed, where braking effort is controlled by fluid pressure (fluid includes compressed air) to apply or to release, that failure of fluid pressure should cause the brakes to be fully applied.

7 On small winding engines where service braking is achieved by direct manual application there should be emergency braking independent of manual effort.

8 Appendix 8.3 lists some alternative methods of brake application.

**Control of manually varied braking torque**

9 Response and sensitivity of the control system should be such that the winding engineman can perform all braking operations easily without the occurrence of adverse hunting, pressure peaks or overshoot.

10 Braking pressure or brake engine travel should bear a known relationship to the winding engineman’s control travel and braking effort should increase progressively and smoothly.

11 Any control valve which includes a pressure feedback mechanism installed to provide braking torque in accordance with paragraph 10, should as far as possible be such that the position of all moving parts can be determined by linear measurement or pressure, as may be appropriate, at any valve position without any dismantling and whilst the valve is working.

12 To achieve the requirements of paragraphs 9 and 10, no additional resilience (for example spring boxes) should be included in the main brake linkage.

**Pressure gauges**

13 Accurate gauges of an adequate size and construction able to withstand service conditions, to show any supply system pressure and any variable operating pressure, should be provided for the winding engineman in addition to gauges required in paragraph 32.

14 Siting of these gauges and size and length of the connecting tube should be such that there is a negligible time lag in gauge reading at the winding engineman’s position.
Emergency trip operation

15 On any brake operating system employing fluid pressure there should be duplicate trip valves, each with its own exhaust line, independent of any control valve. Both trip valves should operate following a safety circuit trip without adverse hunting, overshoot or pressure peaks and their action should preferably be monitored by measuring spindle movement. Should one trip valve fail to operate, indication should be given and the safety circuit trip retained until corrective action is taken.

16 Each trip valve and its associated pipework should be of such sizes and so sited to achieve the minimum delay between the instant of de-energisation of the valve and the moment at which maximum braking effort is reached.

17 On small winding engines where service braking is achieved by direct manual application, there should be duplicate means of applying the brakes independent of manual effort in the event of emergency trip operation.

18 Fast and slow braking application devices should not be installed.

Differential braking

19 Wherever differential braking is required it should be catered for by one of the systems shown in appendix 8.4 and should be such that following an emergency trip no adverse pressure overshoot or adverse dynamic loading of the brake gear occurs.

Design and construction of brake control systems

20 All hydraulic equipment should be so designed and constructed that heat generated is minimal in all parts of the system and adequately dissipated at all times.

21 Standby sources of pressure should be provided.

22 Accumulators or receivers should have sufficient capacity to enable brake engines to make five full double strokes after fluid delivery to the receiver or accumulator has ceased, in order that persons being transported may be brought to a position of safety.

23 Low level of oil or a specific minimum pressure should automatically cause the brakes to be retained in the on position.

24 Correctly designed systems should be used to protect weight loaded accumulators against over travel; protection should be provided against release of the brake from the on position unless there is sufficient fluid in the accumulator.

25 Where accumulators are not fitted, means should be provided for safely controlling the brake under conditions of failure of normal electrical power, unless standby electrical power is available.

26 Visual indication of oil level, and alarm indication of high temperature and low level of oil, should be given.

27 Correctly rated relief valves should be used to protect any pneumatic or hydraulic system.

28 The fluid system should be designed and constructed to withstand, without permanent distortion, a test of at least 1.5 times the maximum working pressure.
29 Any changeover valves, such as for clutch operation, should be designed so that, in any intermediate position, the system fails safe.

30 Appendix 8.5 provides further details of established good practice and refers to Codes and Rules which apply to the design and construction of fluid systems.

**Adjustment of brake control systems**

31 All equipment should be accessible to enable adjustment to be easily carried out.

32 Sufficient accurate and suitably constructed pressure gauges, protected by cocks or valves, and any other necessary measuring devices, should be provided throughout the system to enable adjustments to be checked.

33 The range of adjustments should be adequate to cater for normal variations required in service and each adjustment provided with adequate locking arrangements.

34 Where pressure gauge setting records are not adequate for accurate resetting and where mechanical adjustment exists, suitable data marks should be added to the linkages.

**Design and construction of brake gear**

35 All equipment should comply with Section 81 of the Mines and Quarries Act 1954 or any superseding legislation in force.

36 If a brake is of radical configuration, it should normally be of the caliper type with independently adjustable anchorages, or of the direct action slide located type. Other designs would receive consideration.

37 The brake should contain a minimum number of components, all of which should, as far as practicable, be visible and accessible.

38 Components of the brake should be adequately sized and supported so that their deflection under load, together with any forces resulting from servo-action, do not materially affect pressure distribution over the brake lining.

39 Construction of the brake should be of such a standard that hysteresis effects caused by friction in moving parts of the brake gear together with inaccuracies in brake paths or discs should not adversely affect braking torque.

40 Where two or more components, such as duplicate tie rods or spring nest rods, share load, arrangements should be included for adjustments to be made to equalise loadings.

41 Adequate adjustments should be provided for:

1. Presenting the friction linings to the paths or discs.
2. Clearance of the linings in the brakes off position.
3. The position of the brake engine pistons or cylinder rams.

42 Back stoops to limit outward movement of the brakes should be provided in such a way that compressive loads cannot be applied to the brake linkage.

43 Brake engines or cylinders should be protected against overtravel.
44 On spring applied brakes, the proportions of the spring lengths and the working travel should be such that consistent braking torques are obtained without need for frequent adjustment.

45 If, in order to satisfy the requirement in paragraph 4, the whole of the braking torque has to be taken by one path or disc, all components, drum structure, bearings and supports should be designed and constructed to accept the resultant loading.

46 All brakes should be designed and constructed for ease of dismantling for inspection and maintenance. Where adjustments are provided, there should be data marks to facilitate re-assembly and all adjustments marks to facilitate re-assembly and all adjustments should be provided with adequate locking arrangements. As far as practicable the design and construction of components should be such that they cannot be incorrectly assembled and each component should be clearly identified by a correctly positioned part number.

47 Construction, assembly and alignment of brake gear should be such that there are no adverse built in strains.

48 Wherever possible pivots should be fitted with non-metallic bushes which eliminate need for lubrication. If this is not possible for components where seizure could be critical, the use of similar materials as bearing pairs should be avoided. Points with difficult access which require manual lubrication should be connected to a convenient individual nipple.

49 Monitors should be provided to indicate the operation of the brake.

50 All pins and keys should be positively retained.

51 Brake linings should be secured by suitable proven means.

Component design, materials and manufacture

52 Components of the brake and its control equipment (excluding such items as bearings, linings, seals and packings) which are load carrying when the brake is applied, or taken off, should be designed and constructed for infinite life under the duty originally specified.

53 The design of the system and its components should be capable of being subject to recognised methods of stress analysis and a complete set of stress calculations supplied and approved prior to manufacture. Section 4 contains a list of recommended materials.

54 Paths or discs should have sufficient thermal capacity to enable any specified duty to be carried out; and to enable a complete normal statutory quarterly test, as required by the Coal and Other Mines (Shafts, Outlets and Roads) Regulations 1960 or any superseding regulations in force, to be carried out without delays for cooling. Any brake fade during the test should have no effect on the safety of the installation. Linings, paths or discs should be able to withstand temperatures involved, with the minimum of distortion.

Inspection

55 All components should be subjected to inspection for dimensional accuracy to ensure compliance with design and construction requirements.
56 All components from the brake control lever to the brake shoe anchorages should be non-destructively tested to the standards in Section 5.

**Protection**

57 All exposed moving parts of the installation should be securely guarded in accordance with the requirements of Section 82 of the Mines and Quarries Act 1954 or any superseding legislation in force.

58 Parts which are vulnerable to corrosion or accidental damage during maintenance and work on ropes, should be appropriately protected.

59 Brake paths and brake linings should be protected from contamination by oil, water and grease. As far as is practicable, brake paths should be shielded from direct contamination by any rope lubricant. See appendix 8.6.

**Testing**

60 Design and construction of equipment should be such that safety features required by this section can be demonstrated to be effective during manufacture, at commissioning and in service.

**Electrical equipment**

61 This section does not cover requirements for electrical equipment. Nevertheless any electrical component, connections etc, should be of proven reliable design.

**SUMMARY OF ESSENTIAL FEATURES FOR EXISTING MECHANICAL BRAKES**

62 In part 1A, paragraph 22, reference is made to the fact that essential features have been extracted from the general requirements for new winding engine mechanical brakes, so that they can be applied to mechanical brakes on existing winding engines.

**Brake duty**

63 The brakes should provide the braking torques required by the Coal and Other Mines (Shafts, Outlets and Roads) Regulations 1960, or any superseding regulations in force, produce specified maximum and minimum retardations and cater for any other specified duties of the winding engine, eg rope capping, rope changing, winding abnormal loads, level changing on clutched drum winding engines (refer to appendix 8.1). The retardation of a drum winding engine conveyance should not exceed 1 g in order to minimise risk of injury to persons following application of the brake after an emergency trip. To achieve this, in practical terms, retardation of the drum should not exceed 16 ft/sec² (4.9 m/sec²) and should preferably be less than 12 ft/sec² (3.7 m/sec²). Maximum retardations for friction winding engines are specified by Regulations which are at present being reviewed.

**Retention of braking torque following component failure**

64 Existing mechanical brakes with single line components, the failure of which would prevent application of the brake by either the winding engineman or a safety device, should be appraised to determine whether the brakes can be modified to eliminate these components and, where possible, they should be eliminated. If this cannot be readily achieved, and fatigue design considerations show that single line components have not been designed and manufactured for infinite fatigue life,
these components should be replaced within a defined period based on their fatigue life and their replacements should be designed and manufactured for an infinite fatigue life. Nevertheless, certain single line components (to be specified in the design guide referred to in section 1) although designed for infinite fatigue life should be given a definitive life. All single line components should be operated and maintained within their designed parameters and should be subjected to regular non-destructive testing as specified in section 5 at the intervals shown in the table.

65 On winding engines with dual line systems it is accepted that in the event of failure of a component there may be some loss of braking torque, but the design should be such that the brake still exerts a braking torque sufficient to bring the winding system safely to rest and produces not less than 50% of the normal braking force. Appendix 8.2 gives alternative methods of achieving this requirement. Serious reduction of mechanical braking torque may also occur as a result of contamination of brake paths or linings by oil or moisture or other matter. It is anticipated that in most cases the effect of such contamination would not be greater than the effect of failure of a brake component and thus the effect of contamination would be within the 50% allowance for loss of braking force owing to failure of a component. In this context, to bring the winding system safely to rest means preventing the descending conveyance from passing the lowest landing at a speed greater than that which the pit bottom arresting devices can accept to bring the conveyance to rest at a specified rate. It also means ensuring that the ascending conveyance does not strike the headframe and that the detached capel is not wound into the winding engine house.

**Brake operating systems**

66 The brakes should act directly on paths or discs integral with the drum, and the brake operating system should be so designed where braking effort is controlled by fluid pressure (fluid includes compressed air) to apply or to release, that failure of fluid pressure should cause the brakes to be fully applied.

67 On small winding engines where service braking is achieved by direct manual application there should be emergency braking independent of manual effort.

68 Appendix 8.3 lists some alternative methods of brake application.

**Control of manually varied braking torque**

69 Response and sensitivity of the control system should be such that the winding engineman can perform all braking operations easily without the occurrence of adverse hunting, pressure peaks or overshoot.

70 Braking pressure or brake engine travel should bear a known relationship to the winding engineman’s control travel and braking effort should increase progressively and smoothly.

**Pressure gauges**

71 Accurate gauges of an adequate size and construction able to withstand service conditions, to show any supply system pressure and any variable operating pressure should be provided for the winding engineman in addition to gauges required in paragraph 87.

72 Siting of these gauges and size and length of the connecting tube should be such that there is a negligible time lag in gauge reading at the winding engineman’s position.
**Emergency trip operation**

73. On any brake operating system employing fluid pressure there should be duplicate trip valves, each with its own exhaust line, independent of any control valve. Both trip valves should operate following a safety circuit trip without adverse hunting, overshoot or pressure peaks and their action should preferably be monitored by measuring spindle movement. Should one trip valve fail to operate, indication should be given and the safety circuit trip retained until corrective action is taken.

74. Each trip valve and its associated pipework should be of such sizes and so sited to achieve the minimum delay between the instant of de-energisation of the valve and the movement at which maximum braking effort is reached.

**Differential braking**

75. Wherever differential braking is required, it should be catered for by one of the systems shown in appendix 8.3 and should be such that following an emergency trip no adverse pressure overshoot or adverse dynamic loading of the brake gear occurs.

**Design and construction of brake control systems**

76. All hydraulic equipment should be so designed and constructed that heat generated is minimal in all parts of the system and adequately dissipated at all times.

77. Standby sources of pressure should be provided.

78. Accumulators or receivers should have sufficient capacity to enable brake engines to make sufficient full double strikes after fluid delivery to the receiver or accumulator has ceased, in order that persons being transported may be brought to a position of safety.

79. Low level of oil or a specified minimum pressure should automatically cause the brakes to be retained in the on position.

80. Correctly designed systems should be used to protect weight loaded accumulators against overtravel, and protection should be provided against release of the brake from the on position unless there is sufficient fluid in the accumulator.

81. Where accumulators are not fitted, means should be provided for safely controlling the brake under conditions of failure of normal electrical power, unless standby electrical power is available.

82. Visual indication of oil level and alarm indication of high temperature and low level of oil should be given.

83. Correctly rated relief valves should be used to protect any pneumatic or hydraulic system.

84. The fluid system should be designed and constructed to withstand, without permanent distortion, a test of at least 1.5 times the maximum working pressure.

85. Any changeover valves, such as for clutch operation, should be designed so that, in any intermediate position, the system fails safe.
86 Appendix 8.5 provides further details of established good practice and refers to Codes and Rules which apply to the design and construction of fluid systems.

**Adjustment of brake control systems**

87 Sufficient accurate and suitably constructed pressure gauges, protected by cocks or valves, and any other necessary measuring devices, should be provided throughout the system to enable adjustments to be checked.

88 The range of adjustments should be adequate to cater for normal variations required in service and each adjustment provided with adequate locking arrangements.

**Design and construction of brake gear**

89 All equipment should comply with Section 81 of the Mines and Quarries Act 1954 or any superseding legislation in force.

90 Where two or more components, such as duplicate tie rods, or spring nest rods, share load, arrangements should be included for adjustments to be made to equalise loadings.

91 Adequate adjustments should be provided for:

(1) Presenting the friction linings to the paths or discs.

(2) Clearance of the linings in the brakes off position.

(3) The position of the brake engine pistons or cylinder rams.

92 Back stops to limit outward movement of the brakes should be provided in such a way that compressive loads cannot be applied to the brake linkage.

93 Brake engines or cylinders should be protected against overtravel.

94 If, in order to satisfy the requirements in paragraph 65, the whole of the braking torque has to be taken by one path or disc, all brake components drum structure, bearings and supports should be checked to ensure the resultant loading does not produce an excessive stress.

95 For components where seizure could be critical, the use of similar materials as bearing pairs should be eliminated.

96 All pins and keys should be positively retained.

97 Brake linings should be secured by suitable proven means.

**Component design, materials and manufacture**

98 Components of the brake and its control equipment (excluding such items as bearings, linings, seals and packings) which are load carrying where the brake is applied, or taken off, should be checked and, where necessary, replaced by parts designed and constructed for infinite life in respect of the present duty of the winding engine. Components should be rechecked if the duty is amended. Single line components must be dealt with as in paragraph 64.

99 The design of the system, and its components, should be the subject of an approved method of stress calculation.
100 For replacement items supplied by a manufacturer a complete set of stress calculations should be supplied and approved prior to manufacture. Section 4 contains a list of recommended materials.

**Inspection**

101 All components which transmit force from the brake springs, fluid or weights to braking surfaces should be non-destructively tested to standards in section 5.

**Protection**

102 All exposed moving parts of the installation should be securely guarded in accordance with the requirements of Section 82 of the Mines and Quarries Act 1954 or any superseding legislation in force.

103 Parts which are vulnerable to corrosion or accidental damage during maintenance, and work on ropes, should be protected.

104 Brake paths and brake linings should be protected from contamination by oil, water and grease. As far as is practicable, brake paths should be shielded from direct contamination by any rope lubricant. See appendix 8.6.

**Electrical equipment**

105 This section does not purport to cover requirements for electrical equipment. Nevertheless any electrical component, connections etc should be of proven reliable design.

**APPENDIX 8.1 Specific requirements for new and existing clutched drum winding engines**

1 The following terms are used. When a drum can be disconnected from a winding engine drum shaft by operation of a clutch, it is described as a loose drum; when a drum is keyed to a winding engine drum shaft, it is described as a fixed drum.

**New clutched drum winding engines**

2 Unless otherwise specified, it is envisaged that, when a clutch is withdrawn, clutched drum winding engines should only be used for level changing or rope adjustment purposes. Men should not be wound with a clutch withdrawn.

3 When both drums are clutched to the shaft, the brakes of a clutched drum winding engine should meet the requirements for drum winding engines.

4 The two brakes on the drum to be turned when the other drum is held stationary, should be designed as though the winding system were a single conveyance type.

5 The drum which is being held stationary while the other drum is being turned should be equipped with two brakes, each of which is capable of holding an empty conveyance at the shaft top with a reverse of torque of at least 33%.

6 Means should be provided so that brakes on any drum which is able to be declutched can be tested for compliance with this holding power requirement while the clutch is engaged.
7 Interlocks should be provided to ensure that a conveyance attached to any drum which is to be declutched is at the shaft top, above any keps, before a clutch can be withdrawn.

8 The clutch operating mechanism should be interlocked to prevent withdrawal until the brakes on the drum to be declutched are proven on. The brakes on any declutched drum should be interlocked to prevent their release until the clutch is proved to be adequately engaged.

Existing clutched drum winding engines

9 It is envisaged that, when a clutch is withdrawn, clutched drum winding engines should only be used for level changing or rope adjustment purposes. Men should not be wound with a clutch withdrawn.

10 When both drums are clutched to the shaft, the brakes of a clutched drum winding engine should meet the requirements for drum winding engines.

11 The brake on the drum to be turned, when the other drum is held stationary, should be appraised to ensure that it will hold an empty conveyance at pit bottom with a reverse of torque of 50% (Test 1E of the Model Code for the Testing of Drum Winding Engines, in section 32).

12 The brake on the drum which is being held stationary while the other drum is being turned should be appraised to ensure that it will pass the test described in the next paragraph (Test 1C of the Model Code for the Testing of Drum Winding Engines).

13 TEST 1C: LOOSE DRUM BRAKE. Balance the conveyances and fully apply the loose drum brake. Take the fixed drum brake off with the clutch still fully engaged. Apply power in the downward direction of the loose drum conveyance. The brake should hold power torque at least equal to that required to raise an unclutched empty conveyance from the shaft bottom.

14 An alternative method is to test the brake by setting the loose drum conveyance containing a load just above the keps or, preferably, girders fixed across the shaft top. The load to be used for the test depends on the position of the conveyances when declutching takes place in service. When the normal practice of declutching with the loose drum conveyance at the surface is used, the load should be at least one third of the weight of the conveyance. If, for some reason, it is necessary to declutch in service with the loose drum conveyance away from the surface, the road used for the test at the surface should be at least one third of the weight of the conveyance plus one and one third of the weight of the rope from the surface to the position where the loose drum conveyance is declutched in normal service. Apply the loose drum brake and disengage the clutch. The brake should hold the loaded conveyance, showing that there is a reserve of brake holding torque of 33% when the conveyance is empty. Should braking be insufficient there will be a slight movement on to the keps or girders.

15 Where practicable, interlocks should be provided to ensure that a conveyance attached to any drum which is to be declutched is at the shaft top, above any keps, before a clutch can be withdrawn.

16 The clutch operating mechanism should be interlocked to prevent withdrawal until the brakes on the drum to be declutched are proved on. The brake(s) on any declutched drum should be interlocked to prevent their release until the clutch is proved to be adequately engaged.
APPENDIX 8.2 Retention of braking torque following component failure

Some alternative methods of achieving the requirement in paragraphs 4 and 65 of section 8 are:

1. Provision of two brake paths, each with an independent brake, and a man winding cycle allowing sufficient retardation distance with only one path in use but without excessive retardation with both parts in use.

2. Provision of two brake paths, each with an independent brake, with normal braking less than the maximum possible. Means to be provided for automatic detection of failure of either system and for appropriate increase of braking torque in the other system. Where inadvertent use of increased braking torque could cause danger, the means used should have special consideration.

3. Use of independent multiple unit brakes of radial or disc type with a minimum of two units acting on each of two brake paths or discs and a man winding cycle allowing sufficient retardation distance with one unit inoperative but without excessive retardation with all units operative.

4. Use of duplicate components, each one normally carrying half the load but capable of taking up automatically the whole of the load in case of failure of the other.

5. Use of normally redundant components which automatically take up the load in case of failure of a load carrying component.

APPENDIX 8.3 Brake operating systems

Alternative methods of brake application:

1. Compression spring application, fluid pressure release.

2. Fluid pressure application, fluid pressure release with spring or weight application in case of pressure failure.

3. Direct manual application for small winding engines.

APPENDIX 8.4 Differential braking

One of the following alternative methods should be used:

1. Controlled residual pressures (back pressures) for spring applied brakes.

2. Controlled operating pressures for pressure applied brakes.

3. The use of some of a number of multiple unit brakes suitably arranged to give balanced efforts.

APPENDIX 8.5 Fluid circuit details

1. At least two sources of fluid pressure should be provided:

   (1) for hydraulics, duplicate pump and motor sets each capable of producing the volume and pressure of oil required by the system;

   (2) for pneumatics, duplicate compressors each capable of supplying the volume and pressure of air required by the system;
OR

one suitable compressor, and the mine supply used for the second source of air pressure.

2 The charging stroke of weight loaded accumulators should be restricted to the correct length by automatically cutting off the flow of oil from the pump and diverting the flow to tank. Overtravel protection should be provided by a relief hole in the ram cylinder, the hole being connected to tank. The accumulator should be tested to twice normal working pressure.

3 Fluid level in each tank should be indicated by a sight glass, and a level switch should be fitted to initiate an alarm if the fluid falls to a specified limit above a safe working level. A thermostat should be fitted to monitor return oil temperature and initiate an alarm if there is a rise above the normal working temperature range. The level switch and thermostat should be of an acceptable standard.

4 Pump bedplates should be provided with lips to contain any seepage from glands.

5 Compressed air accumulator system (air – oil) should conform to appropriate British Standards, and to requirements for air receivers included in the NCB (Production) Codes and Rules Reciprocating Air Compressors (Surface and Underground). The oil level in the accumulator should be indicated by a gauge glass and controlled automatically.

6 For a pneumatic system, filtering, drying, and lubrication injection equipment, should be included as necessary to provide air of suitable quality.

7 Air pressure differential should not exceed 10% of the working pressure.

8 Hydraulic systems should be fitted with adequate filters.

9 Hydraulic systems should be designed to use a specified hydraulic fluid and the reservoir marked to indicate the fluid to be used.

10 Where air could be trapped in a hydraulic installation, facilities for bleeding should be provided.

11 On pressure applied brakes an independent means of operating the back-up braking system should be provided to enable maintenance to be carried out on the rest of the system.

APPENDIX 8.6 Prevention of contamination of brake paths and linings

1 The chief causes of contamination are:

(1) Oil – hydraulic or bearing lubrication.

(2) Grease – rope or pin lubricants.

(3) Water – shaft, rain and condensate.

(4) Chemicals – de-greasing fluids.

2 Contamination of paths and linings may lead to changes in friction between them and consequent undesirable changes in rates of retardation and in holding torque. Suggestions relating to the prevention of contamination are set out below.
3. On new winding engine mechanical brakes, oil pipes should be positioned so that, as far as practicable, oil from a burst or damaged pipe or fittings should not cause contamination of brake paths. All oil pipe work should, after installation, be tested to one and one half times maximum working pressure.

4. All lubrication arrangements for pins and journals should be such that any excess lubricant is prevented from containing the brake paths.

5. New drums should be provided with a flange of minimum height 6 in (152 mm) above the brake path and 6 in (152 mm) above the rope.

6. New drums should be encased or shielded to prevent, as far as practicable, rain water, shaft water and rope lubricant from being thrown on to brake paths.

7. Where construction of the house or environmental conditions promote condensation on the winding engine, adequate heating or air conditioning should be provided.

8. Manufacturers of brake linings should supply details of approved de-greasing fluids which will not have a harmful effect on linings.

9. **Electrical braking of winding engines — review of practice**

1. Reference is made in paragraph 25 of Part 1A of the Report to a review of control systems of DC electric winding engines, to determine the feasibility of making electrical braking available, after initiation of an emergency or automatic trip, without the intervention of the winding engineman until the mechanical brake is proved substantially effective.

2. The review dealt with the three present practices involving retention or reinstatement of electrical braking on DC winding engines. These are:

   A. retention of electrical braking until the mechanical brake is applied;

   B. the combination of electrical and mechanical braking systems to give governed rates of retardation;

   C. automatic suppression of all electrical torque following tripping of the safety circuit, with manual facilities to regain electrical braking.

3. The advantages and disadvantages of the three practices are set out below.

   **Practice A**

   4. Electrical braking is retained until the mechanical brake is applied.

   **Method adopted**

   5. The brake is proved on by means of limit switches operated by brake movement. Pressure switches also indicate that the brake is applied at the correct pressure. Four limit switches and two pressure switches are used to ensure duplication. The electrical circuits are so designed that malfunction of any one switch will retain electrical braking.

   6. Circuits, limit switches and pressure switches are tested at the end of each wind to check their condition. If the circuits and their components are not in a ...
healthy condition a visible and audible alarm is given on the winding engine desk. On automatic winding, the winding engine is prevented from being restarted.

**Advantages**

7. Removes electrical driving torque from the motor in the event of an emergency trip (which in itself could have been produced by failure of an electrical component) provided the mechanical brake has been proved on. The system thus prevents any possibility of driving through the mechanical brake with consequent reduction in retardation rates.

8. Allows retention of electrical braking until the mechanical brake is proved on. Use of the emergency stop will leave electrical braking available and give the same effect.

9. On a closed-loop winding engine, if the mechanical brake is not proved on, the winding engine is brought down to creep speed of less than 1 ft/sec (0.3 m/sec).

10. Only simple circuits are required to achieve the objective.

11. Efficacy of the means of detection of brake on is monitored after each wind.

**Disadvantages**

12. Electrical braking cannot be regained should the mechanical brake fail after being proved on.

13. Limit switches require maintenance and adjustment.

14. Brake efficiency is not proved, ie the method does not cater for brake path contamination. Investigations are being carried out as to the possibility of producing a sensitive device to measure brake torque reaction to overcome this weakness.

**Practice B**

15. Electrical and mechanical braking systems are combined to give governed rates of retardation.

**Method adopted**

16. Electrical retardation rates are matched to mechanical braking retardation rates with maximum loads descending.

**Advantages**

17. Retention of electrical braking is allowed if the mechanical brake is defective after an emergency trip, provided this trip has not been induced by specific electrical faults.

18. Circuits to prove the mechanical brake on are not needed.

**Disadvantages**

19. The method is only effective if electrical control circuits are healthy. Failure of electrical control circuits could lead to an attempt by the motor to drive through the mechanical brake.
20. The consequence of an electrical control circuit failure and resultant possibility of driving through the mechanical brake is considered to be greater than when electrical power is removed as in practice A. The probability is that malfunction of an electrical control circuit could have caused the emergency trip.

21. Examination of existing circuits and previous incidents show that the following electrical components are particularly vulnerable:

(1) TACHO GENERATOR. Failure would lead to an overspeed condition due to lack of a reference signal and electrical braking would not be available.

(2) CAMS. Wrongly set or loose cams will cause malfunction of electrical circuits with similar results.

22. Electrical circuits giving combined braking facilities tend to be complex.

**Practice C**

23. All electrical torque is automatically suppressed following tripping of the safety circuit with manual facilities to regain electrical braking.

**Method adopted**

24. After an emergency trip, the current in the DC loop is suppressed to zero by the regulating system.

25. After an emergency trip, the winding engineman can regain electrical braking by operating a pushbutton.

**Advantage**

26. Electrical braking is available after an emergency trip after intervention by the winding engineman provided this trip has not been induced by certain electrical faults.

**Disadvantages**

27. The winding engineman may not be available to press the pushbutton due to sickness, death, slow reaction etc.

28. A trip can occur so near to the end of a wind that there is insufficient time for recovery of electrical braking by the winding engineman to be effective.

29. If the winding engineman uses the pushbutton to regain electrical braking while the mechanical brake is effectively applied, compounding could occur.

**10 Feasibility of retention of electrical braking**

1. As stated in paragraph 29 of Part 1A of the Report tests were carried out on a 1950 hp open-loop DC Ward Leonard winding engine fitted with cam gear and oil servo operated generator field resistance to investigate the feasibility of retaining electrical braking after an emergency or automatic trip until the mechanical brake is proved on.
2 Specification of winding engine:

<table>
<thead>
<tr>
<th>Type</th>
<th>Double parallel drums 20 ft (6.1 m) diameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drive</td>
<td>Direct current motors with inherent electrical braking</td>
</tr>
<tr>
<td>Motor details</td>
<td>2 motors, totalling 1950 hp (1455 kW) 357 rev/min</td>
</tr>
<tr>
<td>Conveyances</td>
<td>2 cages, weighing 6 ton (6.12 tonne)</td>
</tr>
<tr>
<td>Payload</td>
<td>Coal 5 ton (5.08 tonne)</td>
</tr>
<tr>
<td></td>
<td>Men 3 ton (3.05 tonne)</td>
</tr>
<tr>
<td>Depth of shaft</td>
<td>1977 ft (603 m)</td>
</tr>
<tr>
<td>Gear ratio</td>
<td>9.51:1</td>
</tr>
<tr>
<td>Drum speed</td>
<td>37.54 rev/min</td>
</tr>
<tr>
<td>Gear ratio</td>
<td>9.51:1</td>
</tr>
<tr>
<td>Drum speed</td>
<td>37.54 rev/min</td>
</tr>
<tr>
<td>Duty cycle</td>
<td>Acceleration 14.3 sec</td>
</tr>
<tr>
<td></td>
<td>Full speed 35.5 sec</td>
</tr>
<tr>
<td></td>
<td>Retardation 14.2 sec</td>
</tr>
<tr>
<td></td>
<td>Decking time 15 sec</td>
</tr>
<tr>
<td></td>
<td>Full speed 39.3 ft/sec (12 m/sec) at full load</td>
</tr>
<tr>
<td>Control system</td>
<td>DC open-loop Ward Leonard system speed drop (no load to full load) 10% of full speed</td>
</tr>
<tr>
<td></td>
<td>Loop current trip setting 5000 amps</td>
</tr>
<tr>
<td>Inertias</td>
<td>Motors 1500 lb ft sec² (2034 Nm sec²) each at motor shaft</td>
</tr>
<tr>
<td></td>
<td>Mechanical parts 65,100 lb ft sec² (88,264 Nm sec²) at drum shaft</td>
</tr>
<tr>
<td>Winding rope</td>
<td>Locked coil 1.75 in (45 mm) diameter</td>
</tr>
<tr>
<td>Details</td>
<td>Weight 767 lb per 100 ft (1140 kg per 100 m)</td>
</tr>
</tbody>
</table>

**General**

3 The winding engine is primary used for man winding operations. The tests were carried out by the manufacturers of the electrical portions of the winding engine and were witnessed by NCB engineers.

**Purpose of test**

4 (1) To examine the results of retaining electrical braking on an open-loop DC winding engine fitted with cam gear and oil servo operated field resistance until the mechanical brake is proved on.

(2) To ascertain the conveyance final creep speed.

(3) To ascertain the retardation distance in the shaft.

(4) To ascertain the conveyance end of wind speed.
Assumptions made for purposes of the test

5. (1) That a suitable system exists which proves that the mechanical brake is effectively applied.

(2) That the electrical control system functions at the time of failure of the mechanical brake.

(3) If the proving system indicates that the mechanical brake has failed to function correctly then electrical control is retained.

(4) That the winding engine would be tested as found and that no adjustments of the oil servo would be made.

Tests carried out

6. The maximum loop current during electrical braking tests was 4645 amp. The winding engine control circuits were altered so that when the winding engine safety circuit was tripped the mechanical brake was prevented from operating, thus simulating a failure of the mechanical brake. It was also arranged that when the safety circuit tripped, electrical control was retained and the winding engine electrically retarded in the shortest possible time.

7. TEST A: Conditions. Both conveyances unloaded. The winding engine was operated at a rope speed of 20 ft/sec (6.1 m/sec). A record was made of the final steady slow speed attained by the conveyance and the corresponding position of the conveyance in the shaft. This test was repeated a number of times in order to record the final conveyance speed at various positions of the conveyance in the shaft. The results obtained are shown in graphical form in fig 10.1.

8. TEST B: Conditions. Equivalent man load in descending conveyance. An artificial landing was arranged corresponding to three drum turns from the end of wind position by adjusting the automatic contrivance. This advanced the protection to simulate the end of wind when the conveyance was about 200 ft (61 m) above the bottom of the shaft. The loaded conveyance was accelerated downwards by the winding engine from various positions above the artificial landing. The safety circuit was automatically tripped on overspeed by the automatic contrivance as the conveyance approached the artificial landing and the winding engine electrically braked to a lower speed. Just after the conveyance had passed the artificial landing, the overwind switches on the automatic contrivance opened and the mechanical brake was automatically applied. From these tests the distance required to slow down the winding engine to a safe speed, with a descending loaded conveyance using only electrical braking, was determined. Results obtained are shown in graphical form in fig 10.2.

9. Similar tests were carried out using only mechanical braking to retard the conveyance and comparative results are shown in graphical form in fig 10.3. The end of wind conveyance speed can be obtained by observing cage speed when the conveyance is at the artificial landing (0 distance in fig 10.4). Test B illustrates results obtained when the winding engine is used to accelerate the loaded conveyance to a speed which trips the automatic contrivance at the end of wind as in the peak power test. The most stringent quarterly overspeed tests are those made when the peak torque is applied to accelerate the loaded conveyance towards the artificial landing. Test B was undertaken to compare the effectiveness of the protection given by electrical braking only (fig 10.2) with mechanical braking only (fig 10.3) under the test conditions.
10 TEST C: Conditions of test. Equivalent man load in descending conveyance. Tests were made to assess the protection given under the more normal fault condition of failure to slow down at the end of the wind when lowering at a normal steady speed. The overwind switches on the automatic contrivance were readjusted to give more clearance below the artificial landing, so that the mechanical brake would not be applied too soon after electrical controlled retardation had occurred in order to allow a more detailed assessment of the protection afforded. The winding engine was operated at a rope speed of approximately 20 ft/sec (6.1 m/sec) and wound into the retardation zone of the automatic contrivance. The safety circuit associated with the automatic contrivance tripped and the conveyance retarded under the influence of electrical braking only. Results obtained are shown graphically in fig 10.4 – curve B. The change in the main DC loop current that takes place during this test is shown graphically in fig 10.5.

11 TEST D: Conditions of test. Equivalent man load in descending conveyance. The loaded conveyance was accelerated down into the retardation zone of the automatic contrivance so as to trip the safety circuit when the rope speed was approximately 20 ft/sec (6.1 m/sec) using electrical braking only. Results obtained are shown graphically in fig 10.4 – curve A. The change in the main DC loop current that takes place during this test is shown graphically in fig 10.5.

Figure 10.1

This is a web-friendly version of Safe manriding in mines: First Report of the National Committee for Safety of Manriding in shafts and Unwalkable Outlets, originally produced by HM Inspectorate of Mines.
Figure 10.2

Figure 10.3

Figure 10.4

This is a web-friendly version of Safe manriding in mines: First Report of the National Committee for Safety of Manriding in shafts and Unwalkable Outlets, originally produced by HM Inspectorate of Mines.
12 TEST E: Conditions of test. Equivalent man load descending. This test was a repeat of test A using the same test conditions to obtain the final steady speed with the exception that the descending conveyance contained the equivalent man load. Results are shown graphically in figs 10.1 and 10.6.

**Conclusions**

13 The tests show that with the existing control system retention of electrical braking will cause the winding engine to slow down despite mechanical brake failure and the most adverse winding circumstances.

14 Test B simulated the most adverse winding circumstances assuming that a brake failure could occur while the loaded conveyance is being accelerated downwards, by the winding engine, towards the artificial landing. The cage went past the artificial landing at 15 ft/sec (4.6 m/sec) (see fig 10.4 – curve A). Under normal operating procedures it would not be anticipated that these extreme conditions would be met. It is more likely, if speed were not reduced in the prescribed manner, that the automatic contrivance would trip the safety circuit under overspeed conditions and apply mechanical braking. Failure of the mechanical brake under these conditions may result in acceleration of the conveyance.

![Figure 10.5](image)

15 Test D shows that if the speed on the tripping of the safety circuit is 20 ft/sec (6.1 m/sec) the maximum speed at the landing with the winding engine tested would be 10 ft/sec (3.05 m/sec) (see fig 10.4 – curve B). It is obvious that the maximum speed at the landing will vary according to the speed at which the conveyance is travelling when the safety circuit trips. The tests carried out show that the maximum speed it can reach under the worst conditions will be 15 ft/sec (4.6 m/sec) but that a more realistic maximum landing speed carrying a full man load in the descending conveyance with an empty conveyance ascending would be in the region of 10 ft/sec (3.05 m/sec) to 11 ft/sec (3.4 m/sec). On the winding engine tested, maximum speed at the landing could be reduced if the automatic contrivance protection was extended to trip the safety circuit earlier. To achieve a
landing speed of 5 ft/sec (1.6 m/sec), the tripping cam of the automatic contrivance would have to be extended an amount equivalent to 30 ft (9.2 m) of shaft distance.

16 Electrical braking torque could be increased by adjustments to the existing control equipment. For example, the size of orifice governing the emergency retardation rate setting of the Ward Leonard controller could be increased and linkages fitted to the Ward Leonard trip solenoid could be altered to reduce solenoid drop off time.

17 The tests prove that it would be possible on this type of DC winding engine to retain electrical braking until the mechanical brake is proved on. It would be necessary, however, to carry out similar tests on all DC open-loop Ward Leonard winding engines with cam gear and oil servo assistance to establish the maximum speed at the lowest landing and the necessary alterations and modifications to achieve an acceptable value.

11 Torque control scheme for the retention of dynamic braking of an AC winding engine

1 Reference is made in paragraph 31 of Part 1A of the Report, to control schemes for AC winding engines which would enable electrical braking to be retained without the intervention of the winding engineman. A scheme which satisfies the above requirements is shown in fig 11.1.

Figure 10.6

Objective

2 To retain and apply dynamic braking on an AC winding engine after an emergency trip without intervention of the winding engineman. Wherever possible proposals are based on the use of existing dynamic braking schemes particularly those employing liquid controllers.

Method of operation

3 Consider fig 11.1 in which all contacts are shown in the de-energised position.

Normal winding

4 With the safety circuits reset and the mechanical brake on, contacts SC1 and BC1 are open and SC2 is closed.
5 The winding engineman’s lever, in addition to operating potentiometer P, will be provided with contacts to operate the forward and reverse (F and R) contactors and also the dynamic braking (DB) contactor in accordance with the slot selected.

6 When winding normally the winding engineman can select either the forward or reverse contactors to determine the direction of rotation of the motor or, if required, the dynamic braking contactor. Potentiometer P provides a signal to both the DB amplifier and the current error amplifier which is arranged to limit the position of the liquid controller electrodes. The current feedback circuits ensure correct response to the winding engineman’s signal and control torque of the motor.

When an emergency trip occurs

7 When an emergency trip is initiated, the contacts SC1, SC2 and BC1 revert to the condition shown in the fig 11.1 if the mechanical brake is off, also contacts (not shown) energise the DB contactor and de-energise the power contactors.

Figure 11.1

8 This has the effect of:

(1) removing power from the motor if this is being applied at the time;

(2) closing the DB contactor;

(3) applying a present fixed signal to the DB amplifier;

(4) applying the same preset signal to current error amplifier which controls position of the liquid controller electrodes;

(5) when the mechanical brake is proved on, BC1 opens and removes dynamic braking.
Conclusions

9 From the foregoing it can be seen that when an emergency trip takes place, the scheme calls for maximum dynamic braking until the mechanical brake is proved on.

10 The scheme briefly described above and illustrated in fig 11.1 is in skeleton form; in practice, account would be taken of the need to eliminate single line components.

12 Types of control equipment for AC winding engines

In Part 1A, paragraph 32, reference is made to the different arrangements in control equipment used on AC winding engines having open-loop control and without dynamic braking at NCB mines. Details of such equipment are below.

<table>
<thead>
<tr>
<th>Type of control equipment fitted</th>
<th>Number of winding engines</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Drum type controller with grid type resistors. No stator reversing contactor or rotor resistance contactor.</td>
<td>19</td>
</tr>
<tr>
<td>2 Drum type controller with stator reversing contactor. Grid type resistors without rotor resistance contactors.</td>
<td>17</td>
</tr>
<tr>
<td>3 Drum type controller with stator reversing contactor and grid resistors with rotor resistance contactors, without acceleration timers.</td>
<td>1</td>
</tr>
<tr>
<td>4 Drum type controller with stator reversing contactor and grid resistors with rotor resistance contactors and acceleration timers.</td>
<td>3</td>
</tr>
<tr>
<td>5 Master controller and lever gear with reversing contactor and grid resistors with rotor resistance contactors and acceleration timers.</td>
<td>10</td>
</tr>
<tr>
<td>6 Master controller and lever gear with liquid controller but without acceleration device (servo).</td>
<td>43</td>
</tr>
<tr>
<td>7 Master controller and lever gear with liquid controller but with acceleration device (servo).</td>
<td>88</td>
</tr>
<tr>
<td>8 Other.</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>182</td>
</tr>
</tbody>
</table>
13 Automatic contrivances in categories A, B and C

In Part 1A, paragraph 37, reference is made to a list of automatic contrivances which have been categorised on the basis of operating experience:

A acceptance pending critical examination.
B to be phased out in due course.
C to be phased out as soon as practicable.

LIST OF AUTOMATIC CONTRIVANCES BY CATEGORY

<table>
<thead>
<tr>
<th>Category</th>
<th>Acceptable</th>
<th>To be phased out in due course</th>
<th>To be phased out as soon as practicable</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Lilly Duplex</td>
<td>Worsley Mesnes Pneumatic</td>
<td>Walker/Walker Black</td>
</tr>
<tr>
<td>B</td>
<td>Lilly Single Head</td>
<td>ASEA (provisional category)</td>
<td>Black Inertia</td>
</tr>
<tr>
<td>C</td>
<td>Worrall Device</td>
<td>GEC Mine Winder Controller</td>
<td>Black's Modified Torque (BMT)</td>
</tr>
<tr>
<td></td>
<td>Black's Torque (Elec Trip)</td>
<td>H J H King</td>
<td>Black's Torque (Elec Trip)</td>
</tr>
<tr>
<td></td>
<td>Black's Speed</td>
<td>Black's Major</td>
<td>Robey Worsley</td>
</tr>
<tr>
<td></td>
<td>Black's Maxi</td>
<td>Black's Mini</td>
<td>Mesnes Worsley</td>
</tr>
<tr>
<td></td>
<td>Black's Mini</td>
<td>Gardner Hydraulic</td>
<td>Hydraulic</td>
</tr>
<tr>
<td></td>
<td>SSW with Magnetic Switches</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

12 The electrical aspects of automatic contrivances are being examined
13 Speed range limited
14 Black's Torque (Mech. trip) Controllers must be modified to BMT type including removal of Lockheed System. Black's Torque (Elec. type) should be modified to BMT when convenient.

14 Schedule of improvements to category A type automatic contrivances

In Part 1A, paragraphs 38 and 42.4, reference is made to a schedule listing improvements to category A type automatic contrivances. One of each type in category A was fully dismantled, examined on the basis of mechanical aspects of reliability, fail-safe features and operational features, and calculations for factors of safety were also carried out for the speed sensing components. A minimum factor of safety of five was adopted, based on the ultimate strength of the material and the maximum operating load divided by the area of section. The following schedule lists undesirable features or low factors of safety found and
Manufacturers have been asked to make certain improvements as stated in the schedule. The electrical aspects of automatic contrivances in category A are being examined.

<table>
<thead>
<tr>
<th>Type of controller</th>
<th>FOS calculation</th>
<th>Comments on the operation, reliability and fail-safe features</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lilly Duplex</td>
<td>Satisfactory, but see comments at 5 in the next two columns.</td>
<td>1. The input shaft boss had been fitted with a brass bush which was not standard on new controllers.</td>
<td>Accepted for correcting wear at this bearing.</td>
</tr>
<tr>
<td>Lilly Single Head</td>
<td></td>
<td>2. In all the brass components, varying amounts of porosity had been found, the greatest being in the governor body.</td>
<td>GEC notified. No action – existing controllers satisfactory.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3. Cracks between cast arm holes in the gear wheels had been found.</td>
<td>Gear wheels redesigned and material changed to Grade 17 CI.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4. Square corners at change of section and a slot found in the governor body.</td>
<td>Existing components satisfactory; GEC removing square corners and slot in future manufactured items.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5. Low FOS for the governor ball arm.</td>
<td>Series of overspeed tests carried out at MRDE which verify that the ball arm is satisfactory and the square neck corner on the governor body has adequate FOS at twice normal out of balance load.</td>
</tr>
<tr>
<td>Worral Device</td>
<td>Satisfactory.</td>
<td>1. Square corners found at changes of section.</td>
<td>No action: the introduction of radii involves major design changes.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2. The mercury switch quadrant arm locking arrangement considered inadequate.</td>
<td>Existing controllers to be fitted with Nyloc nuts. GEC to fit Nyloc nuts on new controllers.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3. Some components manufactured from light alloy metal.</td>
<td>Aluminium components are satisfactory for surface winding engines but it is noted that this controller is extensively used on haulages underground.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4. Taper split pins not opened at the ends.</td>
<td>GEC have arranged for quality control to check that split pins have been opened at the ends.</td>
</tr>
<tr>
<td>Type of controller</td>
<td>FOS calculation</td>
<td>Comments on the operation, reliability and fail-safe features</td>
<td>Action</td>
</tr>
<tr>
<td>--------------------</td>
<td>-----------------</td>
<td>-------------------------------------------------------------</td>
<td>--------</td>
</tr>
<tr>
<td>GEC Mine Winder</td>
<td>Satisfactory</td>
<td>5. Should the vacuum in the glass be lost, oxidising of mercury on surface of the glass could cause permanent short circuit and failure to detect overspeed.</td>
<td>Electrical aspects are being reviewed.</td>
</tr>
</tbody>
</table>

**GEC Mine Winder** Satisfactory except for 3.

1. All shafts in the controller should have suitable radii at changes in shaft sections.

2. Stirrup hinge bracket should be redesigned to eliminate vertical slot adjustment.

3. Three screwed tappets/clevises on 2 above require modification to eliminate bending moment on the threaded components. Calculations show two items with FOS of less than 5 to 1: ie Linkwork ‘gold club foot’ FOS 3.83; forked end FOS 2.10.

4. The two adjustable bias counterweights in the controller could be made integral with the fabricated arm.

5. Overspeed switches were clamped by screws through slotted holes in the switch body; these should be made more positive.

**Black’s Modified Torque Controller (BMT)**

Satisfactory. The retardation profile lever relies on a taper fit at one end. This should be pinned. This modification is being carried out by Black’s on new and existing controllers.

**Black’s Speed Black’s Major Black’s Maxi**


**Black’s Mini Controller**

Satisfactory. The switch lever assembly is a taper fit on the switch shaft and relies entirely on friction for its connection. Suggest that a pin be fitted. This modification is being carried out by Black’s on new and existing controllers.
<table>
<thead>
<tr>
<th>Type of controller</th>
<th>FOS calculation</th>
<th>Comments on the operation, reliability and fail-safe features</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gardner Hydraulic</td>
<td>Satisfactory</td>
<td>This controller is chain driven. NCB have agreed to fit oil</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>from the drum shaft. There is no protection against failure</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>of the chain drive or loss of oil pressure.</td>
<td></td>
</tr>
<tr>
<td>SSW with Magnetic</td>
<td></td>
<td>This is an electrical device. Electrical aspects are being</td>
<td></td>
</tr>
<tr>
<td>Switches</td>
<td></td>
<td>reviewed.</td>
<td></td>
</tr>
</tbody>
</table>

15 Typical broken shafts protection system for an automatic contrivance

1 Paragraph 40 of Part 1A of the Report, points out that safe operation of an automatic contrivance depends on the integrity of its drive from the winding engine drum.

2 A typical automatic contrivance broken shaft protection system is shown in fig 15.1. This system monitors all drive components up to the speed elements of the contrivance but could be elaborated to cover distance elements as well. A description of operation and a circuit diagram are given overleaf.

3 With the DC supply on and the winding engine stationary, contacts SDRF2 and Sp.Sw.2 are closed with relays SDRF2 TGF and DSFR energised. A normally open contact on relay DSFR is closed enabling the safety circuit to be completed. As the winding engine accelerates the tachogenerator energises relay SDR and contact SDR starts to change over at 4 ft/sec (1.2 m/sec). Relay SDRF1 is energised and closes contact SDRF1. Speed switch Sp.Sw. changes over contacts Sp.Sw.1 and Sp.Sw.2 at 5 ft/sec (1.6 m/sec). At 6 ft/sec (1.8 m/sec) relay SDRF2 is de-energised opening contact SDRF2. This condition exists throughout the full speed period of the winding cycle.

4 In the retardation period, the above contact changeover procedure is reversed as the speed is reduced from 6 ft/sec (1.8 m/sec) to 4 ft/sec (1.2 m/sec).

5 If the driving shaft fails when the rope speed is above 6 ft/sec (1.8 m/sec) any part of the winding cycle, relay DSFR de-energises and opens the safety circuit.

6 If the drive to, or the output from the tachogenerator fails when the rope speed is above 5 ft/sec (1.6 m/sec) then relays TGF and DSFR are de-energised opening the safety circuit.
Sp.Sw, is a speed detection switch mounted on the automatic contrivance, and operated from the governor.

Sp.SW.1 contacts close at a rope speed of 5 ft/sec (1.6 m/sec).

Sp.SW.2 contacts open at a rope speed of 5 ft/sec (1.6 m/sec). SDR is a speed detection relay supplied from a tachogenerator independently driven from the winding engine drum.

A changeover contact on relay SDR allows the follower relay SDRF1 to energise at a rope speed of 4 ft/sec (1.2 m/sec) and causes the follower relay SDRF2 to energise at a rope speed of 6 ft/sec (1.8 m/sec).

TGF – Tachogenerator failure relay.

DSFR – Drive shaft failure relay. (Contact in the safety circuit).

Fig 15.1

16 Typical electronic supervisory device for an automatic contrivance

1 In paragraph 40 of Part 1A of the report, reference is made to the use of a supervisory device as an alternative to monitoring the automatic contrivance itself. An electronic version of this device is described below.

2 The electronic supervisory device is designed to measure the conveyance speed from the rotation of the drum shaft. It can be arranged to trip the winding engine safety circuit if the conveyance is travelling at a speed in excess of the predetermined value, and so bring the winding engine to rest by removal of power.
and application of the mechanical brake, or provide an alarm signal. The speed of the conveyance is compared with various preset values, some of which may only apply when winding men or when winding to insets. It may be checked at increments of 1 ft (305 mm) of shaft depth.

3 Speed limits can be set to within 0.5 ft/sec (150 mm/sec) or less at low speeds. Once set up, the speed settings are stable and do not drift. The equipment is designed so as to be able to provide automatic correction where a bi-cylindro conical drum is used or the rope coils onto a drum in more than one layer.

4 The device can be connected to a computer system for analysis of the winding pattern or to detect performance deterioration. It is constructed from solid-state components which are duplicated and a fault light indicates if there is a discrepancy between the two sections. The brake is also applied if the device is disconnected from the drum shaft, or if any printed circuit board inside the device is removed. The present depths can be offset, en bloc, to allow the conveyance to be deliberately wound faster than the speed limits, without the conveyance’s approaching bank or pit bottom. A portable test set may be used for testing the device without moving the conveyance.

5 Later developments of semiconductors now allow the use of micro-computers, duplicated, to measure speed at every unit interval against a prestored characteristic of speed against distance.

6 The unit requires a mains power supply at 240 V or 110 V, single phase, 50 Hz; however, a float charged standby battery giving a minimum of 4 hours reserve is provided.

17 Review of safety circuit concepts

1 These notes on the concepts from which present safety circuits were developed are those referred to in paragraph 45 of Part 1A of the Report.

DC winding engine safety circuits

2 In the early 1940s if the winding machine mechanical brakes were fast enough in operation so that the winding engine complied with statutory landing speed regulations, then on many installations excessive rates of retardation and shock loading of part of the winding system would occur.

3 To overcome this problem on DC winding engines employing the Ward Leonard system of control, the concept of dividing the safety circuit into primary and secondary parts was introduced so that electrical braking could be employed. An oil servo rheostat in the generator field was also introduced at the same time. This device, through tripping of a solenoid valve and operation of the safety circuit, enabled the rate of reduction in the generator field to be preset and so provide the required degree of electrical braking. The concept of primary and secondary safety circuit was applied in the following manner.

Primary safety circuit

4 Connected into this part of the safety circuit were the trip contacts of devices which detected electrical abnormalities such as field failure, electrical overload, motor generator overspeed and emergency stop. Tripping of the circuit was arranged to initiate the application of the mechanical brake and remove electrical power at the same time. Electrical baking was not retained on the basis that an electrical fault had initiated operation of the safety circuit.
Secondary safety circuit

5 Into this part of the safety circuit were connected the trip contacts of devices which detected mechanical abnormalities such as overspeed, brake wear and in certain cases overwind. Tripping of this circuit initiated electrical braking by de-energising the solenoid of the hydraulic valve on the oil servo operated generator rheostat, so that a predetermined value of electrical braking was available to bring the winding engine down to creep speed when the mechanical brake was applied. If however a trip occurred when a conveyance was so near the end of a wind that creep speed could not be attained before an overwind occurred, electrical braking was removed and the mechanical brake applied.

Closed-loop control

6 The concept of a primary and secondary safety circuit continued to be used after development of closed-loop control schemes. These schemes enabled the distance travelled by a conveyance to be reduced when the winding engine was being electrically braked from full speed to creep speed. Lower creep speeds could be attained before electrical braking was removed and the mechanical brake applied.

Electrical and mechanical safety circuits

7 One manufacturer adopted a similar concept to the one described above but used the terms electrical and mechanical instead of primary and secondary respectively. In this instance the electrical safety circuit operated in the same manner as described above for the primary safety circuit. However in the case of a trip of the mechanical safety circuit the result was different from that produced by a secondary safety circuit trip as described above. In this instance electrical power was retained and the mechanical brake applied but the degree of electrical braking was governed by the closed-loop speed control system so that it was zero when the mechanical brake was effectively retarding a normal descending load.

AC winding engine safety circuits

8 Safety circuits of AC winding engines are divided into two parts designated main and back-up.

Main safety circuit

9 In this part of the circuit are the trip contacts of devices that detect the main abnormal conditions such as overwind, overspeed and emergency stop. When any of these devices trip the circuit, electrical driving power to the winding engine motor is removed, but the facility to apply dynamic braking is retained if the winding engine is so equipped with this facility.

Back-up safety circuit

10 The back-up safety circuit has trip contacts of devices associated with electrical equipment such as tank and cover interlocks, reverse freeze interlocks and remote main circuit breaker trip. Operation of the trip contacts opens this part of the safety circuit, de-energising the safety contactor and under voltage coil on the main circuit breaker to remove all power and cause the mechanical brake to be applied.

18 Typical examples of safety circuit trip devices

Reference is made in Part 1A, at the end of paragraph 46, to typical devices which
trip safety circuits in Categories 1a, 1b, 2 and 3 under abnormal conditions. The following list shows examples of such devices or abnormal conditions which cause safety circuit trips.

**Category 1A**

- Overspeed.
- Overwind (automatic contrivance).
- Slack rope.
- Emergency pushbutton.

**Category 1b**

- Ultimate overwind (headframe ultimate limit switch).

**Category 2**

- One of the brake solenoids not reset or not operated.
- Loss of motor field.
- Instantaneous overcurrent (winding engine motor armature).
- Loss of tachogenerator field.
- Opening of main circuit breaker.
- Loss of generator excitation.
- Loss of control supply to closed-loop system.
- Cam gear overtravel (Ward Leonard control cams).
- Motor generator set overspeed.
- No start timer.
- Sustained overload.
- Exciter overload.
- Amplidyne overload.
- Generator overvoltage.
- Insufficient brake system fluid.
- Automatic contrivance drive shaft failure.

**Category 3**

- Bearings above permissible temperature.
- Armature earth leakage (main loop).
- Winding engine motor windings above permissible temperature.
- Auto/manual control selector (misuse).
- Brake overtravel warning.

**Note** It will be necessary to add or to vary these trip functions depending on the type of winding engine.

### 19 Protection of safety circuits against electrical faults

1. The protection of winding engine safety circuits against electrical faults is referred to in Part 1A at the end of paragraph 46. In the following statement the problem of maintaining the integrity of safety circuits is considered.

**General**

2. The safety circuits and brake solenoid circuit which, when de-energised, initiate retardation of a winding engine after an emergency trip, should be so arranged that no fault remains undetected which could render those circuits ineffective.
3. Those parts of the safety circuit into which are connected the contacts of devices which detect abnormal conditions in Categories 1a, 1b and 2 should each have at least two contactors. These should have their coils connected in parallel, be of proven reliability, and be monitored and cross interlocked to ensure that they operate correctly.

4. At least two brake solenoids should be included to initiate operation of the mechanical mechanical brake after an emergency trip. These solenoids should be of proven reliability, and be monitored and cross interlocked to ensure that they operate correctly.

5. Circuits associated with detection of Category 1 abnormal conditions should be physically segregated from each other and from other circuits, as necessary, to eliminate the risk of fault or leakages which might lead to malfunctions and danger. These circuits should not be included in the same cable with other circuits. All cables used to connect the trip contacts of devices which detect Category 1 abnormal conditions should have individually screened cores, the screens being securely connected to earth at one end of the cable and for example to a switch case at the other. Wiring in cubicles does not require the use of screened cores, but precautions should be taken to ensure adequate segregation. Outside the winding engine house the cables should be armoured, but inside the winding engine house they may be unarmoured provided they are installed or physically protected to prevent mechanical damage. Specifications of suitable armoured or unarmoured cables are included in section 20.

6. On existing winding engines safety circuits are often supplied from a source such as an auxiliary transformer or exciter set which is used for many other purposes. It is considered that this arrangement is unsatisfactory and that sufficient independent sources of supply should be provided so that the contacts of devices for detection of abnormal conditions associated with each category or sub-category can be separately supplied. Independent sources of supply would permit rapid fault finding, facilitate provision of satisfactory earth fault protection, and provide a choice of function that would be performed by the earth fault protection relays, ie visually and/or audibly indicate the presence of a fault to the winding engineman. Where contacts in a safety circuit are provided with parallel connected flag indication relays, each relay should have a self-operated series contact, and a suitable current limiting resistor of such value and integrity that there is no risk of the safety contactors’ being retained by the current through this part of the circuit. Cables between the contacts of devices detecting Category 1 abnormal conditions and trip indicator flag relays should comply with the requirements for circuits associated with detection of Category 1 abnormal conditions.

7. The use of interposing or follower relays should be avoided in circuits associated with Categories 1a, 1b and 2 abnormal conditions unless the integrity and reliability of the system is maintained. Devices for detecting Category 1 abnormal conditions should be of high reliability and of a type in which the normally closed contacts are positively driven to the open position; that is the devices should not rely on springs which on failure might allow the contacts to remain closed. Where this requirement for operation of positively closed contacts cannot be met, any alternative device used should not be inferior in performance and operation.

Use of fuses for safety circuit protection

8. A common method which has been used to protect safety circuits is to earth one pole of the system and connect a fuse in the other, but great care is required in the choice of the rating and type of fuse.
9 Typical values of current in a safety circuit are, 2 amp to enable the safety contactors to pick up with the operating coils connected in parallel, and a retaining current of 0.25 amp when economy resistors are inserted on completion of closure of the contactors. (The economy resistors are employed to reduce to a minimum the delay on opening). In this case a fuse with a rating of 2 amp would most likely fail from fatigue after a number of re-setting operations, so a fuse rating of 3 to 4 amp would be required in practice. The use of fuses in relation to earth fault protection on safety circuits is discussed below.

10 The type of fault which gives rise to the greatest danger is that which results in the shorting out of one or more sets of tripping contacts in the safety circuit so that an abnormal condition is not detected. To maintain the integrity of the circuit, faults of this nature must be prevented or detected immediately.

11 Consider the following typical winding engine safety circuit with trip contacts connected in series, of which C represents one or more of the trip contacts.

The circuit illustrates the types of fault likely to occur around C, except for an open circuit fault which would trip the circuit. These faults are represented by resistors R1, R2, R3 and R4:

![Circuit Diagram]

R1 and R2 represent faults from the terminals of the device or cable cores to the casing of the device.

R3 represents a direct fault across a trip contact which can result from tracking across the insulation between the terminals of the tripping device, or a short between the unscreened cores of the cable connected to the device. This type of fault cannot be detected by protection devices and therefore, by placing earthed screening between terminals, leads and cable cores should be converted to an earth fault which can be normally detected.

R4 represents the resistance of the earth path from the case of the tripping device to the common earth of the safety circuit. In a good installation the value of R4 would be low. In a bad installation the value of R4 is likely to be high, but this high value cannot be detected with simple protection systems.

12 To assess the effect R4 has on the integrity of the safety circuit several cases are considered as follows:
(1) \( R_4 = \text{infinite ohms.} \)

If voltage drop across resistances \( R_1 \) and \( R_2 \) is less than or equal to 20 volt, the safety contactors will not open. Therefore these contactors will hold in if \( R_1 + R_2 \leq 92 \text{ ohm} \) and the condition will not be detected.

(2) \( R_4 = 0 \text{ ohms.} \)

The fuse is fully loaded if \( \frac{R_1 R_2}{R_1 + R_2} = 25 \text{ ohm} \) and any decrease in this resistance will cause the fuse to blow. Also, whatever the value of \( R_1 \) and \( R_2 \) when the contact \( C \) opens, the potential across \( R_2 \) and the safety contactors is always zero and these contactors will open.

(3) \( R_4 = \text{infinite value.} \)

If the fuse has not blown, \( R_4 + \frac{R_1 R_2}{R_1 + R_2} \geq 25 \text{ ohm.} \)

An infinite number of values can be given to the three resistances but generally speaking if \( R_4 > 25 \text{ ohm} \) then \( R_1 \) and \( R_2 \) can drop to low values without being detected and in many cases the safety contactors will not open.
(4) The most distant tripping device is likely to be the headframe ultimate limit switch and taking the length of cable to this device to be say 200 m then the value of R₄ will be approximately 0.5 ohm.

Let R₄ + \( \frac{R₁R₂}{R₁ + R₂} \) = 25 ohm so that the fuse does not blow.

The voltage appearing across R₂ + 372 ohm also appears across R₄ and is likely to be approximately 90 volts since R₂ is included, which will prevent the safety contactors from opening. This voltage would cause a current of approximately 180 amp to flow through R₄ and consequently R₁, but if the fuse is not to blow, R₁ will have such a value that the voltage drop across it is in excess of 100 volt. Therefore whatever values are chosen for R₁ and R₂ to be compatible with the formula

\[
0.5 + \frac{R₁R₂}{R₁ + R₂} = 25 \text{ ohm}
\]

insufficient current will flow in the safety contactors to prevent them from opening.

In the special case where R₁ = R₂ and

\[
R₄ + \frac{R₁R₂}{R₁ + R₂} = 25 \text{ ohm}
\]

the limiting value for R₄ is 22.5 ohm if the safety contactors are to be prevented from opening. Therefore, a good installation where the cable armouring and screening are well connected at each end of the cable will have a good factor of safety against the safety contactors not opening owing to combined faults to the casing of any tripping device.

13 Notwithstanding the above remarks, any fault from the terminal of a safety circuit device to the case of the device should not be allowed to persist; and a reliable system of earth fault detection, having fail-safe features, is preferred for those parts of a safety circuit concerned with abnormal conditions in Categories 1 and 2. Two such earth fault protection systems were examined, one for DC and one for AC supplies, but the latter was considered to be unsatisfactory.

**Fail-safe DC earth fault protection system**

14 Figure 19.1 shows a complete DC safety circuit incorporating fail-safe earth fault protection using earth fault relays (designated E/F1 and E/F2) with 10 kilo-ohm coils. Examination of the circuit shows that the two earth faults relays are closed under healthy conditions by the current flowing from positive through E/F1 to the common earth through E/F2 to negative. Earth fault current at A on the safety circuit trip contacts, will flow back to negative via the common earth connection and E/F2; this shunts the current flowing through E/F1. An earth fault having a
resistance of 6.7 kilo-ohm will cause E/F1 to drop out opening contacts E/F1-2 and tripping the safety circuit on earth fault. The earth fault relays will be held open by mechanical latch.

![Diagram](image.png)

**Figure 19.1**

15 If an earth fault of 7 kilo-ohm (just in excess of the trip level) were on the positive line (say at (A)), then a fault developing on the negative line (say at (D)) would only have to fall to 1.8 kilo-ohm before E/F2 drops out. To check these parameters a test switch with six operational positions is incorporated:

- At position 1, a 5 kilo-ohm resistor is switched to earth on the positive line. EFI opens and latches out.
- At position 2, a 7 kilo-ohm resistor is inserted between the negative line and earth and a 1.5 kilo-ohm resistor between the positive line and earth E/F1 opens and latches out.
- Position 3 is an off position.
At position 4, a 7 kilo-ohm resistor is inserted between positive line and earth and a 1.5 kilo-ohm resistor between negative line and earth. E/F2 opens and latches out.

At position 5 a 5 kilo-ohm resistor is inserted between negative line and earth, E/F2 opens and latches out.

Position 6 is an off position.

16 To check the trip sensitivity at various points around the circuit a specific series of tests using a rheostat to simulate a safety contactor coil of 40 ohm was carried out as follows:

(1) Earth fault applied at (A) – Relay E/F1 tripped out when fault resistance was 6.8 kilo-ohm followed by relay E/F2 when the fault resistance had been reduced to 4.4 kilo-ohm.

(2) Earth fault applied at (B) – Relay EF1 tripped out when fault resistance was 2.3 kilo-ohm followed immediately by relay E/F2.

(3) Earth fault applied at (C) – Relay E/F2 tripped out when fault resistance was 4.7 kilo-ohm followed immediately by relay E/F1.

(4) Earth fault applied at (D) – Relay E/F2 tripped out when fault resistance was 6.2 kilo-ohm followed by relay E/F1 when the fault resistance had been reduced to 4.1 kilo-ohm.

17 The same tests were carried out using the rheostat to simulate 50 ohm, 100 ohm and 200 ohm safety contactor coils, the results being as follows:

Single earth faults with various safety contactor coil resistances

<table>
<thead>
<tr>
<th>E/F trip sensitivity</th>
<th>RESISTANCE</th>
<th>RESISTANCE</th>
<th>RESISTANCE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>50 ohm</td>
<td>100 ohm</td>
<td>200 ohm</td>
</tr>
<tr>
<td>kilo-ohm</td>
<td>kilo-ohm</td>
<td>kilo-ohm</td>
<td></td>
</tr>
<tr>
<td>At (A)</td>
<td>6.7</td>
<td>6.7</td>
<td>6.7</td>
</tr>
<tr>
<td>(B)</td>
<td>2.1</td>
<td>2.5</td>
<td>2.7</td>
</tr>
<tr>
<td>(C)</td>
<td>5.3</td>
<td>3.8</td>
<td>1.7</td>
</tr>
<tr>
<td>(D)</td>
<td>6.5</td>
<td>6.5</td>
<td>6.5</td>
</tr>
</tbody>
</table>

18 It was realised that this circuit would not trip with an earth fault at mid point which, in this case, is the mid point of either of the 560 ohm economy resistors. The worst condition which could arise would be an earth fault at another point on the circuit. To check the behaviour of the circuit under such conditions, tests were carried out with mid point solidly earthed and a variable resistance to simulate an earth fault at various points around the circuit. Again, safety contactor coil resistances of 40 to 200 ohm were simulated and results, tabulated below, indicate the sensitivity of the circuit.
Earth faults with mid point earthed and various safety contactor coil resistances

<table>
<thead>
<tr>
<th>E/F trip sensitivity</th>
<th>40 ohm</th>
<th>50 ohm</th>
<th>100 ohm</th>
<th>200 ohm</th>
</tr>
</thead>
<tbody>
<tr>
<td>At A</td>
<td>220 ohm</td>
<td>130 ohm</td>
<td>130 ohm</td>
<td>130 ohm</td>
</tr>
<tr>
<td>B</td>
<td>50 ohm</td>
<td>50 ohm</td>
<td>30 ohm</td>
<td>40 ohm</td>
</tr>
<tr>
<td>C</td>
<td>130 ohm</td>
<td>90 ohm</td>
<td>80 ohm</td>
<td>10 ohm</td>
</tr>
<tr>
<td>D</td>
<td>220 ohm</td>
<td>120 ohm</td>
<td>120 ohm</td>
<td>120 ohm</td>
</tr>
</tbody>
</table>

**Conclusions**

19 (1) The circuit in fig 19.1 is stable and sensitive for all single earth faults except those occurring at mid point. By using wire wound resistors on ceramic formers for the economy resistors, together with well laid out high integrity components for the safety circuit contactors, the possibility of an earth fault occurring at or near the mid point is remote.

(2) Even if there were an undetected earth fault at or near the mid point, a second earth fault on the safety circuit trip contacts would be detected before the fault resistance dropped to a level which would permit the flow of sufficient current to hold in the safety circuit contactors. Therefore the circuit is safe under these conditions.

20 Typical cable specification for winding engine safety and control circuits

1 The specification given below for cable with screened cores is that referred to in paragraph 46(1) of Part 1A of the Report.

**Armoured cable**

2 The cable should generally comply with BS 6346: 1969 expect as modified below, and should be multicore, PVC installed (600/1000 volt), cores individually screened, PVC sheathed, single wire armoured, black PVC sheath overall.

**Constructional details**

<table>
<thead>
<tr>
<th>No of cores</th>
<th>2</th>
<th>4</th>
<th>6</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conductor, number and diameter (mm)</td>
<td>7/0.67</td>
<td>7/0.67</td>
<td>7/0.67</td>
<td>7/0.67</td>
</tr>
<tr>
<td>of plain copper wires</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nominal thickness of insulation (mm)</td>
<td>0.7</td>
<td>0.7</td>
<td>0.7</td>
<td>0.7</td>
</tr>
<tr>
<td>Tape</td>
<td>Polyethylene terephthalate film, 0.025 mm thick applied with a 20% overlap</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Screen</td>
<td>Spiral layer of 0.40 mm diameter plain copper wires applied with a lay of not less than 6 nor more than 10 times the pitch circle diameter</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No of cores</td>
<td>2</td>
<td>4</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>------------</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Tape</td>
<td>Polyethylene terephthalate film, 0.025 mm thick applied with a 50% overlap.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Lay-up

(i) Screen lay to oppose the conductor lay
(ii) Polyethylene terephthalate film tapes to have the same lay as the conductor.
(iii) Cores to be laid in the same direction as the screen lay, the 6 and 8 core cables having the cores laid around a suitable solid PVC centre

| Thickness of inner sheath (mm) | 0.8 | 0.8 | 0.8 | 0.8 |
| Size of armour wire (mm) | 0.9 | 1.25 | 1.25 | 0.8 |
| Thickness of outer sheath (mm) | 1.4 | 1.5 | 1.6 | 1.7 |
| Nominal overall diameter (mm) | 15.5 | 18.3 | 21.3 | 25.6 |
| Maximum conductor resistance at 20°C (ohm/km of cable) | 7.41 | 7.41 | 7.41 | 7.41 |
| Maximum screen resistance at 20°C (ohm/km of cable) | 6.2 | 6.2 | 6.2 | 6.2 |

Identification of cores
For 6 and 8 core cable, core identification should be effected by means of black numerals printed on white core insulation. The interval between the adjacent numbers on the same core should not exceed 75 mm.

Sheath compound
The overall sheath compound should be type 1A.

Unarmoured cable

3. The cables should comply generally with BS 6004: 1969 except as modified below, and should be multicore, PVC insulated (600/1000 volt), cores individually screened and black PVC sheathed overall.

Constructional details

<table>
<thead>
<tr>
<th>No of cores</th>
<th>2</th>
<th>4</th>
<th>6</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conductor, number and diameter (mm) of plain copper wires</td>
<td>7/0.67</td>
<td>7/0.67</td>
<td>7/0.67</td>
<td>7/0.67</td>
</tr>
<tr>
<td>Nominal thickness of insulation (mm)</td>
<td>0.7</td>
<td>0.7</td>
<td>0.7</td>
<td>0.7</td>
</tr>
<tr>
<td>Tape</td>
<td>Polyethylene terephthalate, 0.025 mm thick applied with a 20% overlap</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Screen</td>
<td>Spiral layer of 0.40 mm diameter plain copper wires applied with a lay of not less than 6 times nor more than 10 times the pitch circle diameter.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tape</td>
<td>Polyethylene terephthalate film, 0.025 mm thick applied with a 50% overlap.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
21 Systems safety assessment

Introduction

1. In Part 1A, paragraphs 51 and 52, reference is made to exploratory discussions with the Civil Aviation Authority (Airworthiness Division) following which it became apparent that their methods used in handling safety assessment and approvals are likely to be applicable to the work now being undertaken by the National Committee for Safety of Manriding Shafts and Unwalkable Outlets. Similar discussions took place with the Systems Reliability Service, an industrial branch of the Safety and Reliability Directorate of the UK Atomic Energy Authority, Culcheth, Nr Warrington.

2. This section describes the systems safety analysis techniques of these and similar organisations. Representatives from each of the two organisations, Civil Aviation Authority (CAA) and Systems Reliability Service (SRS) have outlined their methods and discussions have been held on the applicability of these to the current examination of winding engine safety.

Definition of systems, systems analysis and systems safety analysis

A system

3. The term system is used in the dictionary sense of a set or assemblage of things connected, associated or interdependent so as to form a complex unity. We can refer, for example, to a winding system, a brake system or a control system. This definition can be made somewhat more specific for technological or engineering purposes as an orderly arrangement of linked, interacting components or elements designed to perform specified functions in specified conditions.
4 The elements of a system are not confined to items of mechanical or electrical hardware. Human operators or maintenance personnel are equally elements of the system as are operational or repair procedures. A management system, to take an extreme example, could operate in principle with only verbal links.

5 Attention is drawn to specified functions (or outputs) under specified conditions (or inputs). It is not possible to use the term system in a precise way unless the primary and subsidiary functions of the system are defined. Whether a design or installation is in fact satisfactory depends upon the specified functions being correctly performed within the limitations imposed by the environment and conditions. For example, in the case of a winding system, the performance in terms of load to be raised, depth, cycle time, winds per shift, etc form part of the functional specification. The conditions within which the specified performance is to be met must also, however, be as specified: eg the supply voltage should be within specified tolerances, and suitably trained operators available.

**Systems, sub-systems and elements**

6 While a complete winding installation can be defined as a system, including the entire complex of equipment, operations and procedures necessary to raise and lower men, materials and mineral, a brake system is also an entity in itself. Viewed from the standpoint of the winding system, the brake system is a sub-system.

7 A system can be viewed as a hierarchy of sub-systems which at the lowest level are composed of elements. Providing the appropriate interfaces are clearly defined, any system, sub-system or element can be considered as a separate entity.

**Systems analysis and systems engineering**

8 In simple terms, systems analysis involves the sub-division of a complex system with specified performance, objectives and constraints into sub-systems and elements, together with the determination of the performance objective of each of the sub-systems necessary to meet the overall objectives of the system.

9 The term performance objectives is used rather than performance since, in general, systems analysis is used at the design stage, when performance has been specified but not demonstrated. Systems analysis may lead to tentative designs of sub-systems which may be examined and modified in the light of new data. The design proceeds by a repetitive process, as elements and sub-systems are designed, assembled and tested.

10 These processes are not new – any design project is either consciously or unconsciously such a process. It is merely that large and complex systems involve the co-ordination of many engineers from a variety of disciplines and organisations. A more explicit formalisation of the system into sub-systems then becomes important, since each separate task can be related by all to the overall objectives.

11 Design and other engineering functions embracing this type of analysis are termed systems engineering.

**Systems safety analysis**

12 Just as a system has a specified function or functional objective, so it may also have specified safety or reliability objectives; and the specified conditions may include risk of failures, errors or external events. In principle, systems safety analysis consists of the division of the overall system into its sub-system, or
hierarchy of sub-systems, and the determination of the maximum acceptable failure risk of sub-systems or elements which allow the overall safety objectives to be achieved.

13 However, there is a complex range of possible faults in a winding system. Considering the mechanical braking system, for example, a situation can be envisaged when the protective system should initiate emergency braking. Perhaps two emergency brake solenoids are de-energised but each has a fault risk; and each of the safety circuit relays in turn has a finite probability of faulty operation. Hydraulic valves or piping may become blocked; one or more brake engines may be employed but a common failure may result from contamination of brake paths.

14 The task of overall safety assessment is formidable and has given rise to a number of procedures involving logic and analytical tools, documentation procedures etc in order to make some progress towards its solution. Before proceeding to an outline of the two systems examined, a brief indication of some of the principal techniques is presented in simple form.

**Intuitive methods**

15 Intuitive methods of analysis should not be discounted – they work well in many situations. Intuitive analysis seems to be a subconscious mixture of two basic formal methods, deductive and inductive analysis, either or both of which can be used in the general analysis.

**Deductive method**

16 The deductive method involves a how could this have happened? approach, reasoning from the general to the particular. The analyst specifies a state of existence of the overall system, an undesired outcome, and tries to identify the system elements that could contribute to its occurrence. The fault tree analysis is such a process.

17 A fault tree consists of a diagram of events which may occur, all dependent one upon another and connected by AND or OR gates. An example of a simple fault tree is in fig 21.1. The difference between the gates is that flow through an AND gate is possibly only when all the events listed occur; flow through an OR gate occurs when any of the events listed occurs. Fig 21.1 illustrates the case of a tank with associated pipes and valves, and the undesired outcome is fuel spill. In this simple example, only OR gates are used.

18 By using a schematic diagram of the installation in conjunction with the fault tree, recommendations for increased protection from fuel spill become evident. There is a need for a tank level indicator and alarm, fail-safe valves, installation of gas indicator alarms to ensure early discovery of leaks, and proper maintenance of valves, pipes, flange gaskets, tank interior and exterior. These devices can also be duplicated in such a manner that if one fails the second device will stop the situation from becoming critical. The amount of protection will depend on the safety standard required for the system and, to establish this, proper quantification of the fault tree is necessary. For example, it may be relatively easy to make the chance of a fuel spill less, but it is more difficult to quantify the probability of a fuel spill.

**Inductive method**

19 The inductive method involves a what happens if? approach in which one reasons from the particular to the general. The analyst identifies the possible states of existence of the system elements and sequentially tries to determine the possible
effects of each on the overall system. Failure mode and effect analysis is one example of this technique.

Figure 21.1 Simplified fault tree for fuel spill

**Redundancy**

20 A high degree of safety or reliability in an item of equipment may be very difficult to assure. A method frequently adopted is to duplicate or multiplicate the equipment so that if one unit fails, there remains at least one equipment capable of functioning satisfactorily. By building in redundancy in this way it may well be possible to provide the degree of safety required. A common example is that of a dual braking system for road vehicles.

21 A similar technique may also be adopted for critical instruments which give warning or operate cut-outs when dangerous conditions occur. There does arise however an additional problem since it is often a point of design for the instrument to fail to safety, ie failures generate false alarm conditions. When there are serious objections to unnecessary alarms it may be preferable to adopt a voting system; for example in a triplicated monitor system, if only one monitor indicates danger this is disregarded though indicated as a fault requiring attention, but when two or three indicate danger full emergency procedure is initiated.

**Diversity**

22 A technique related to redundancy, but superior to it, is diversity. Instead of duplicating a function by installing an additional identical piece of equipment, the function is also performed by a different method with as few common elements as possible. The danger arising in redundancy systems based on multiplication is that of common path failures. When extremely high reliability systems are required,
faulty maintenance procedures or errors for example could introduce common
mode failures. While these are naturally to be guarded against in design one of the
best sureties is provided by diversity.

Outline of Civil Aviation Authority safety assessment methods

General features

23 The CAA approach involves a statement or definition of the system and its
safety objectives, and a detailed study of possible failures, errors, events and
effects (defined in paragraphs 26 to 40 below). However, experience of analysing
complex systems has led to the appreciation that a complete analysis of all
possible failures and their combinations becomes unwieldy and finally
unmanageable. The analysis therefore proceeds in the reverse direction by
enumerating the possible dangerous effects. These are traced back through the
system by analysing the ways in which each effect might arise (deductive method).

24 A fault tree of logic diagram is constructed which shows in visual form the
multiple ways in which a given failure or undesired outcome can arise. This has an
important value in itself as a patent display of the factors which have been
considered (or not considered) in the assessment process. When many engineers,
from varying disciplines, organisations and interests (manufacturers, users,
inspectorate) are involved this is a vital aid in communication.

25 The numerical probabilities of individual failures or events etc should also be
established and used to build up the overall figure of risk, as far as practicable.
Where this is not possible or can only be applied in part, reliance has to be placed
on engineering judgement backed by past experience.

Definitions

26 The following definitions closely parallel those used by the CAA but have been
translated to a winding system context.

27 AN OCCURRENCE. A condition involving a potential lowering of the safety of
the system.

28 A FAILURE. An occurrence in which part or parts of the winding system fails or
malfunctions. Failure includes:

(1) A single failure.

(2) Independent failures in combination within a system (eg a brake system).

(3) Independent failures in combination involving more than one system (eg a
brake system and a motor control system).

Note: Categories (2) and (3) above take into account:

(a) any undetected failure that is already present;

(b) such further consequential failures as would reasonably be expected to
follow the failure under consideration.

29 AN EVENT. An occurrence which has its origin outside the system as defined
(eg strike by lightning on the winding engine).
30  AN ERROR. An occurrence arising as a result of incorrect action by any person directly involved in the operation including winding engineman, banksman, onsetter, maintenance personnel etc.

31  FREQUENT. Likely to occur with a frequency greater than once every $10^5$ winds. This implies a frequency of twice or more a year for a heavy duty winding engine, and correspondingly less for medium and light duty winding engines. For all winding engines, the number of such occurrences will be hundreds a year if the type of occurrence applies to most types of winding engine, but proportionately less if it applies only to a fraction.

32  REASONABLY PROBABLE. Likely to occur with a frequency less than once in $10^5$ winds but greater than once in $3 \times 10^4$ winds. For a heavy duty winding engine this is likely to occur on average every few years; and over all National Coal Board winding engines tens of times a year if the type of occurrence is applicable to most winding engines.

33  REMOTE. Likely to occur with a frequency less than once in $3 \times 10^4$ winds but greater than once in $10^5$ winds. This is not likely to occur in the life of the majority of winding engines, but considering all winding engines operated by the National Coal Board it may happen about once a year if the occurrence is applicable to most winding engines.

34  EXTREMELY REMOTE. Unlikely to occur more frequently than once in $10^5$ winds. Considering all winding engines operated by the National Coal Board is not likely to happen more than once every ten years or so even if the occurrence is applicable to most winding engines.

35  EXTREMELY IMPROBABLE. So extremely remote that it does not have to be considered as possible to occur.

Notes relating to paragraphs 31 to 35

(1) It is important to appreciate that the probability of occurrences quoted above relate to total numbers of winds, not to man winds. The latter are estimated at one fifth to one tenth of all winds. This, if an occurrence is extremely remote and it is such that it applies equally to winding men as to mineral, the likelihood of a catastrophic effect with multiple fatalities (implying that it is a man wind) is not more than 1 or 2 in $10^9$ winds.

(2) The probabilities are based on the following estimates:

- A wind is any single journey in a shaft.

- A heavy duty winding engine makes more than $2 \times 10^5$ winds/year.

- A medium duty winding engine makes more than $10^4$ but less than $2 \times 10^5$ winds/year.

- A light duty winding engine makes less than $10^4$ winds/year.

- Man winds are one tenth to one fifth of all winds.

- Total number of winds made by winding engines operated by the National Coal Board is of the order of $25 \times 10^6$ per year.
36 AN EFFECT. A situation arising as a result of an occurrence.

37 MINOR EFFECT. An undesirable departure from normal performance requiring action by system operators, e.g. marginal departure from the cycle during acceleration, maximum speed or deceleration, overheating of liquid controller during shaft examination resulting in an erratic wind etc. In a man wind it does not involve a likelihood of injury or even alarm.

38 MAJOR EFFECT. A serious undesirable departure from normal performance, resulting in buffeting, excessive deceleration, excessive rope slip, significant overtravel etc. In man winding it is likely to result in considerable alarm and concern to men travelling in the conveyance but not in fact likely to result in injury.

39 HAZARDOUS EFFECT. An effect which, if men are involved would entail a clear risk or likelihood of injury, perhaps death; for example overtravel resulting in operation of the detaching hook, dropping the conveyance through a distance of a few feet due to slack rope etc.

40 CATASTROPHIC EFFECT. An effect such as a complete failure of conveyance suspension, major loss of braking, overwinding at high speed. In the case of man winding such an effect is likely to result in multiple injuries and fatalities.

Safety objectives

41 CAA’s safety objectives are stated in terms of the permissible frequency of effects of the various degrees of severity. In a winding context they would typically be:

(1) (a) For all causes the total probability of a catastrophic effect for all winding engines (operated by the National Coal Board) should be extremely remote and the total probability of a hazardous effect during man winding should be remote or extremely remote. It is important to realise the magnitude of the task presented by such an objective.

(b) Systems operating without failures or errors should in no way prejudice continued safe operation.

(c) No single failure, or combination of failures, not considered extremely improbable, should result in a catastrophic effect.

(d) Remote failures should not result in any effect more serious than a major effect.

(e) Recurrent failures should not result in an effect more serious than minor.

(2) The design of the systems and controls, indicators and alarms, and the training and operating procedures should be such as to minimise the possibility of errors by enginemen, banksmen and onsetters.

(3) The design of the systems and associated components, and the system inspection and maintenance procedures should be such as to minimise the possibility of errors by maintenance and similar personnel.

(4) The winding system manufacturers should state the safety levels of the equipment which are needed to be consistent with these objectives. These safety levels should be agreed by the user and Inspectorate.
42 The requirement that a catastrophic effect shall be not more probable than extremely remote, ie not more probable than once in $10^8$ winds, implies that in man winding it is not more probable than about once in $10^9$ winds, assuming that the number of man-winds is one tenth of the total number of winds.

43 Making certain simplifying assumptions it is possible to express such probabilities in terms of Fatal Accident Frequency Rate (FAFR), defined as the number of fatal accidents experienced during an aggregate total of $10^8$ hours of exposure to a particular occupational risk. If we assume that the probability of a man being killed in a cage is comparable to the probability of a catastrophic occurrence, ie $10^{-9}$ per wind, then the corresponding FAFR is 3. This is approximately the risk of death while travelling on a bus or staying at home, and slightly less than for British Industry generally – see appendix.

**Detailed assessment procedure**

44 The sequence of steps involved is best presented as a flow or activity diagram, fig 21.2. The complete assessment procedure is of course a major task and this section is confined to some explanatory comment on the steps, with a few diagrams as illustrations.

1. Define the system, including it’s safety and production objectives and define the location of the system’s interfaces with the other systems of interest

2. Generate overall functions or situations which create hazards

3. Examine the constituents of these hazards

4. Form specific groups of these constituents, where each group leads to the overall hazard

5. Examine, for each group
   (1) the engineering features
   (2) the operator’s function
   (3) any external or other influences

6. Formulate dependence diagram for each function which demonstrates the significance of each constituent

7. Carry out some form of numerical analysis (piece part count analysis etc) as a tool to estimate the possible frequency of the overall hazard but particularly to record the significance of each component

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**Figure 21.2** Activity diagram for CAA safety assessment

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This is a web-friendly version of *Safe manriding in mines: First Report of the National Committee for Safety of Manriding in shafts and Unwalkable Outlets*, originally produced by HM Inspectorate of Mines.
STEP 1. The system (whether the complete winding engine or some smaller system, e.g., the mechanical brake system) is defined by the drawings, material and other specifications such as operational and maintenance procedures. Interfaces need some care in definition. For a complete winding engine one interface is with the electricity supply system. The range of voltage to be expected, the performance under reduced supply voltage or, in the absence of supply are all necessary parts of the definition of the system. The probability of complete loss of supply is also likely to be required, particularly if there is some increased risk associated—e.g., if men have to be brought to the surface by some emergency means. Again, taking a mechanical case, it is important to have a clear definition of the winding system interface at the surface—e.g., whether or not the tub rams system is to be included.

STEPS 2, 3 and 4. These steps consist of the grouping of various generic hazards into logical categories. Some assistance is gained by considering the essential functions for which the system has to provide. Fig 21.3 is an attempt to present the first steps towards such a grouping in a winding context.

![Diagram of Winding System](image)

Figure 21.3 First steps towards hazard grouping

45 Each of the major hazards can be developed into a detailed logic or dependence diagram; an example is presented in fig 21.4. This is one limb, branching from the generic hazard lack of control of conveyance motion. Fig 21.4 has been constructed on the basis of a possible system for a modern winding engine; a simplified drawing of such a system is provided in fig 21.5. Steps 5, 6 and 7 (fig 21.2) involve the detailed consideration of the design, and the associated failure potential of the sub-systems or components in each constituent of the diagram. The sum total of the engineering insight and judgement, experience when available, and the judicious use of related failure data from similar equipment or components is brought to bear at this stage.
As the dependence diagram is studied, the major risks evident from case histories and/or engineering judgement are broken down to a point where particular features emerge as dominant or until a satisfactory level of safety is made evident. Examination of the dominant features, eg consideration of the importance of some common mode failure, may invoke a modification of the design, possibly a radical one, or perhaps an acceptance of a greater hazard than originally desired.

Typical of the dominant features in a winding context are such single line components as the suspension rope and rope attachments, and common failure conditions such as brake path contamination, a situation evident from fig 21.4. It is necessary to determine whether evidence supports a rate of failure in any way of these cases which is significantly worse than that required in the safety objectives. Such factors are not easy to establish, but they are necessary to assure that safety objectives are being met realistically.

The need to use numerical data whenever possible is implicit in the treatment at this stage. In its absence, one is led, in effect, into weighting the constituents in the best alternative way – by engineering judgement. A practical limit is inevitably finally imposed by time and expense.

**Additional points**

While CAA state the safety objectives, define the framework within which the analysis must be constructed and are ultimately responsible for the acceptance or
rejection of a particular analysis or assessment, the manufacturer (in their case the aircraft manufacturer) is required to present the case (ie the analysis and evidence) that a design meets the objectives. The designer/manufacturer must thus be intimately associated with all aspects of the analysis and is responsible for the presentation of the detailed safety analysis for a specific design.

![Diagram of a possible modern winder](attachment:Figure_21_5.png)

**Figure 21.5** Diagram of a possible modern winder

### Systems reliability service

50 SRS was set up in 1970 to make available to industry the extensive experience which had been built up in the UK Atomic Energy Authority on the assessment of the safety and reliability of industrial plants. Assessments became available to process industry that were quantitative, being based on the derivation of numerical probabilities for the occurrence of various modes of system failure. If the failure of a system is a potential source of hazard a protective or warning device may be required and the assessment will need to be extended to cover the likelihood that this in turn will fail, and to examine the further consequences, again on a quantitative basis. Data has been collected for a wide range of electronic, electromechanical, light mechanical, pneumatic and hydraulic components and this collection formed the basis of the SYREL data bank which is freely used for SRS assessments. Techniques have been developed for the analysis of the data and for synthesising system models for complete plant analyses. Examples of failure rate data for components, equipments and systems are given in table 21.1 and fig 21.6.
Figure 21.6 Failure rates for parts, equipment and systems

Objectives

51 The service has three main objectives:
(i) To undertake reliability projects and provide a consultancy service for industry on a confidential basis.
(ii) To provide a service to associate members who share an interest in reliability assessment and would be able to participate in the data bank activities.
(iii) To carry out research and development in reliability technology.

Summary of system analysis methods generally adopted by SRS

52 SRS methods are in many ways similar to those used by CAA. There is however a stronger theoretical and mathematical basis in probability, control and system theory, which allows rigorous treatment of problems. This provides a firm foundation on which to base practical work and provides a route to the understanding and solution of more difficult cases: for example there are considerable problems in defining, measuring and using reliability data for human operators and such problems are the subject of research by SRS.

53 The outline given below of the steps in SRS analysis certainly indicates a close correlation with those in a CAA analysis and an impression is gained that in normal project assessment work there may not be much difference. Essential constituents of the first stage of the analysis are:

(1) Define the system and its boundaries.
(2) Understand the system and how it functions.
(3) Set out the safety or reliability objectives in quantified terms.
(4) Define categories of failure affecting safety.
(5) Prepare a model of the system in diagrammatic form, breaking it down into sub-systems or elements (see paragraphs 6 and 7 of this section) appropriate to the level of analysis being carried out.

(6) Draw up logic flow diagrams as required – this will also entail a close study of the system and its reliability.

(7) Examine all sub-systems or elements for their modes of failure and the effects that these produce on the system – this places faults in categories of importance.

(8) Apply data to the model to obtain values for the criteria of interest.

54 Although these constituents comprise only a first stage of an analysis they should, when completed, yield answers to most of the important questions, viz:

(1) Whether the system is capable of performing its design function.

(2) Whether the safety or reliability objectives are likely to be met.

(3) Whether weaknesses exist in the logic and whether they can be eliminated.

(4) Where areas of high failure rates lie, and whether these rates can be improved.

(5) Whether there are areas of doubt which call for a more detailed analysis.

(6) Whether plans or assumptions for testing and/or maintenance frequencies need to be modified.

55 Depending on the answers to the above questions it may be necessary to proceed in one or two alternative directions. One may decide to inject new data into the system corresponding to improved design and/or test and maintenance schedules, and to carry out a fresh analysis. Alternatively one could go to a second stage and perform a more detailed analysis of sensitive areas. For this type of equipment analysis, the techniques are the same in essence but are at the component breakdown level. This type of analysis can give a very good guide to an equipment’s fault rate under the particular application; it can also give a useful fallout of information, for example:

(1) Whether the equipment is appropriate for the particular application.

(2) Whether there are any design weaknesses in the equipment.

(3) How frequently the equipment should be maintained or tested in its system application.

(4) How sensitive its failure is to environment, human error, testing, maintenance and operating variables.

56 The need to go to component analysis in depth is dictated by how critical an item is at the next level of analysis, i.e., at the equipment level.

57 From these particular benefits the following points emerge: the analytical process leads to an understanding of the system and its parts which, particularly in respect of failure and its effects, would be difficult to acquire in any other way; and the numerical process leads to much better communication on reliability problems.
and highlights weak points so that sound engineering judgement can be applied where it is most effective. Quantifying should not, therefore, be regarded as an end in itself.

**Value of systems safety analysis**

58 The advantages of using a systems safety analysis fall into two main categories: firstly, the systematic, logical and patent display of hazards and their dependence on specific events or failures even when only qualitative information is available; and, secondly, the major additional gain when quantitative failure or incident data can be used.

**Qualitative treatment based on logical dependence**

59 Systems analysis requires a discipline demanding precision and clarity in:

(1) The description or definition of the system itself and those external influences which affects its function and safety.

(2) The specification of safety and operational objectives as far as practicable in quantitative terms.

(3) The presentation of all hazards considered, in a comprehensive organised pattern including logical dependence.

60 These requirements are straightforward and unexceptional; but the resultant benefits of such a systematic, consistent and patent display of the system with its potential hazards and failures are considerable. It constitutes a primary vehicle for communication between, and integration of, the efforts of mixed discipline groups which more complex systems are almost sure to require. In the winding context, for example, electrical, mechanical and instrumentation engineers, metallurgists and reliability specialists must contribute and interact successfully, while the danger of narrow, conflicting or opposing trends must be minimised. There is a similar need for a common language and clarity between manufacturers, users and the Inspectorate. For example, it is more important to specify the level of safety required in terms as quantitative as possible. Terms such as, to prevent danger to men ascending or descending are, in engineering use, almost as unhelpful as the term large factor of safety. The designer and purchaser in fact will have to settle on a real or estimated value and it is far preferable that the value be stated and the factors involved presented. At minimum, ratios of improvement are required in relation to existing or to other hazards.

**Quantitative treatment**

61 When quantitative data can be employed, a further major advantage is obtained over an analysis in which qualitative data only are used because:

(1) Comparison between one method of reducing a hazard and another becomes possible, so that effort can therefore be directed.

(2) A limit can be placed on the effort and expenditure involved by setting and realising specific safety objectives.

62 These advantages are of such significance that, in spite of the scepticism and resistance to the use of systems safety analysis, there is good justification for a careful appraisal of any relevant data that can be obtained. Similarly this fact justifies expenditure on fault data collection, analysis and application.
63 In many cases there is value in using data with a quite wide tolerance superimposed, which may be due to lack of knowledge or varied conditions, since the sensitivity of certain critical components or sub-systems overshadows others. When this occurs, lesser factors can often be dismissed as minor in spite of a wide bracket on the failure rate data employed.

**Conclusion**

64 (1) Safety assessment techniques have been developed over the past 20 years or so and are firmly established in a number of fields where safety is a dominant factor – in nuclear power installations, aircraft and, increasingly in chemical engineering plant.

(2) These techniques are relevant to coal mining problems such as winding engine safety and are expected to constitute a useful tool for engineers and management.

(3) Since the Systems Reliability Service of the UK Atomic Energy Authority operates a commercial service based on their substantial experience, the most suitable means of speedily carrying out a pilot study to establish the practical usefulness of assessment techniques is to place a contract with SRS.

(4) If the pilot assessment study proves of value and assessment work is continued on a routine basis (not only in connection with winding) it would be necessary to set up a small group of engineers competent in this technology.

(5) However well designed a system may be, some risk remains – Safety Assessment techniques constitute the best available method of answering the question how great is that risk, and a safety objective in an engineering or specification document must, in effect, define the acceptable risk.

(6) Important advantages result from the ability to use reliable numerical data; for this reason existing incident data need examination to derive quantitative data where possible, and, for the future, an incident reporting system should be adopted which permits easy recovery of relevant data.

**Table 21.1** Average component failure rates for mechanical, pneumatic and hydraulic components

<table>
<thead>
<tr>
<th>Type of component</th>
<th>Failures per one million hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bellows</td>
<td>5.0</td>
</tr>
<tr>
<td>Diaphragms, metal rubber</td>
<td>5.0</td>
</tr>
<tr>
<td></td>
<td>8.0</td>
</tr>
<tr>
<td>Gaskets</td>
<td>0.5</td>
</tr>
<tr>
<td>Rotating seals</td>
<td>7.0</td>
</tr>
<tr>
<td>Sliding seals</td>
<td>3.0</td>
</tr>
<tr>
<td>O ring seals</td>
<td>0.2</td>
</tr>
<tr>
<td>Filters, blockage leakage</td>
<td>1.0</td>
</tr>
<tr>
<td>Fixed orifices</td>
<td>1.0</td>
</tr>
<tr>
<td>Variable orifices</td>
<td>5.0</td>
</tr>
<tr>
<td>Type of component</td>
<td>Failures per one million hours</td>
</tr>
<tr>
<td>--------------------------------------------------------</td>
<td>--------------------------------</td>
</tr>
<tr>
<td>Restrictors</td>
<td>5.0</td>
</tr>
<tr>
<td>Pipes</td>
<td>0.2</td>
</tr>
<tr>
<td>Pipe joints</td>
<td>0.5</td>
</tr>
<tr>
<td>Unions and junctions</td>
<td>0.4</td>
</tr>
<tr>
<td>Hoses, heavily stressed</td>
<td>40.0</td>
</tr>
<tr>
<td>lightly stressed</td>
<td>4.0</td>
</tr>
<tr>
<td>Ducts</td>
<td>1.0</td>
</tr>
<tr>
<td>Pressure vessels, general</td>
<td>3.0</td>
</tr>
<tr>
<td>high standard</td>
<td>0.3</td>
</tr>
<tr>
<td>Relief valves, leakage</td>
<td>2.0</td>
</tr>
<tr>
<td>blockage</td>
<td>0.5</td>
</tr>
<tr>
<td>Hand-operated valves</td>
<td>15.0</td>
</tr>
<tr>
<td>Ball valves</td>
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</tr>
<tr>
<td>Solenoid valves</td>
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</tr>
<tr>
<td>Control valves</td>
<td>30.0</td>
</tr>
<tr>
<td>Pistons</td>
<td>1.0</td>
</tr>
<tr>
<td>Cylinders</td>
<td>0.1</td>
</tr>
<tr>
<td>Jacks</td>
<td>0.5</td>
</tr>
<tr>
<td>Pressure gauges</td>
<td>10.0</td>
</tr>
<tr>
<td>Pressure switches</td>
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</tr>
<tr>
<td>Bourdon tubes, creep</td>
<td>0.2</td>
</tr>
<tr>
<td>leakage</td>
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</tr>
<tr>
<td>Nozzle and flapper assemblies, blockage</td>
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</tr>
<tr>
<td>breakage</td>
<td>0.2</td>
</tr>
<tr>
<td>Ball bearings, heavy duty</td>
<td>20.0</td>
</tr>
<tr>
<td>light duty</td>
<td>10.0</td>
</tr>
<tr>
<td>Roller bearings</td>
<td>5.0</td>
</tr>
<tr>
<td>Sleeve bearings</td>
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</tr>
<tr>
<td>Shafts, heavily stressed</td>
<td>0.2</td>
</tr>
<tr>
<td>lightly stressed</td>
<td>0.02</td>
</tr>
<tr>
<td>Pins</td>
<td>15.0</td>
</tr>
<tr>
<td>Pivots</td>
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</tr>
<tr>
<td>Couplings</td>
<td>5.0</td>
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<tr>
<td>Belt drives</td>
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</tr>
<tr>
<td>Spur gears</td>
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<td>Helical gears</td>
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<td>Friction clutches</td>
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<tr>
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<tr>
<td>lightly stressed</td>
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<tr>
<td>Hair springs</td>
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</tr>
</tbody>
</table>
### APPENDIX 21.1

#### Risk to life criteria

1. In many industries, and notably the Chemical Industry, the risk to life is expressed in deaths per $10^8$ exposed hours. The term exposed hours means the period of time during which a person is exposed to risk by virtue of his presence in a particular location or performing a particular activity. The unit of $10^8$ hours is the average working life (100 000 hours) aggregated for a work force of 1000 people. A fatal accident frequency rate (FAFR) of fatalities per $10^8$ hours is adopted in order to avoid the use of very small figures.

2. Some relevant FAR values are quoted below:

<table>
<thead>
<tr>
<th>Type of Component</th>
<th>Failures per one million hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calibration springs, creep breakage</td>
<td>2.0</td>
</tr>
<tr>
<td>Vibration mounts</td>
<td>9.0</td>
</tr>
<tr>
<td>Mechanical joints</td>
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</tr>
<tr>
<td>Grub screws</td>
<td>0.5</td>
</tr>
<tr>
<td>Nuts</td>
<td>0.02</td>
</tr>
<tr>
<td>Bolts</td>
<td>0.02</td>
</tr>
<tr>
<td>Rack-and-pinion assemblies</td>
<td>2.0</td>
</tr>
<tr>
<td>Knife-edge fulcrums, wear</td>
<td>10.0</td>
</tr>
</tbody>
</table>

3. For non-industrial activities:

<table>
<thead>
<tr>
<th>Activity</th>
<th>FAFR per $10^8$ hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Staying at home</td>
<td>3.0</td>
</tr>
<tr>
<td>Travelling by bus</td>
<td>3.0</td>
</tr>
<tr>
<td>Travelling by train</td>
<td>5.0</td>
</tr>
<tr>
<td>Travelling by car</td>
<td>57</td>
</tr>
<tr>
<td>Travelling by air</td>
<td>240</td>
</tr>
<tr>
<td>Travelling by motor cycle</td>
<td>660</td>
</tr>
</tbody>
</table>

---

This is a web-friendly version of Safe manriding in mines: First Report of the National Committee for Safety of Manriding in shafts and Unwalkable Outlets, originally produced by HM Inspectorate of Mines.
**Application of FAFR to winding system manriding activities**

4 The average total risk to life in the mining industry is about 17 per $10^8$ hours. This, however, includes the risk of fatalities during coal cutting activities. Whilst such a value may be accepted by men engaged in these activities, it is reasonable to suppose that the exposure when manriding in winding operations should be much less. An FAFR comparable to that incurred by travelling on a bus or train would seem to be more in keeping with manriding. Taking Sowby’s figures, let it be supposed that an FAFR of 3 per $10^8$ exposed hours is accepted during manriding.

**Relationship between FAFR and the probability of a hazard**

Consider 1 man:

Suppose a man-wind lasts for 2 minutes – 1/30 hour (the journey being counted as the total time involved in entry into the cage, travelling, and exit from the cage).

Then the *fatal accident risk* per wind corresponding to an FAFR of 3 is

$$3 \times \frac{1}{30} \times 10^8 = 10^9$$

i.e. an FAFR of 3 corresponds to a 1 in $10^9$ chance that a cage passenger will be fatally injured during a given wind.

Suppose the man makes 2 journeys per day for 250 days a year, then the annual risk of a fatal accident during man-winding would be:

$$2 \times 250 \times 10^9 = 5 \times 10^7$$ per working year.

Assuming a working lifetime of 40 years, the overall risk would be:

$$40 \times 5 \times 10^7 = 2 \times 10^8$$ per working lifetime.

**References**


**22 Tests of prototype pit bottom buffers**

1 In Part 1A, paragraph 57, reference is made to the results of tests made on pit bottom buffers in a shaft at Glapwell Colliery and in an impact testing machine at the Safety in Mines Research Establishment (SMRE), Buxton. Both types of test are described in this report and correlation is established between them. Static tests have also been made to determine the fundamental characteristics of the buffers. Details of these tests are presented in the Metallurgy Paper 75/4B produced by SMRE and Report No TD/MT(75)87 produced by the Mining Research and Development Establishment (MRDE).

2 To provide a basis for design a provisional performance specification was proposed. This required that, for a maximum impact velocity of 10 ft/sec (3 m/sec), maximum deceleration should not be greater than 2.5 g and mean deceleration should not exceed 1.0 g. Tests showed that the buffers did not meet the
performance specification in all respects. However, since the specification was somewhat arbitrary, the use of such buffers is not precluded and both specification and buffer design are open to modification.

3 One of the recommendations made in the Markham Official Report was that all solid landings in shafts be replaced by suitable arresting devices below the lowest winding level as soon as possible. Many schemes for producing a soft landing were submitted by manufacturers and members of the public. These were examined and initially the one selected for development was a type of buffer, proposed by Cable Belt Limited, which absorbs energy by flexure of fabric reinforced rubber walls bolted to steel plates.

4 This section presents test results, describes design modifications and compares deceleration values measured at the colliery and on the testing machine. Factors to be considered in future development are discussed.

**Buffer performance specification**

5 Provisionally, buffer performance should be based on that specified for oil buffers in British Standard 2655 Part 1 1970 Lifts, Escalators, Passenger Conveyors and Paternosters. The criteria in BS 2655 considered to be applicable are:

1. Mean deceleration to be not greater than 1.0 g.
2. Maximum deceleration to be not greater than 2.5 g.
3. Decelerations greater than 2.5 g for periods less than 40 milliseconds may be ignored.

**Specimens tested**

6 A sectional view of a typical buffer is shown in fig 22.1. The walls in each tier are made of a material comprising a rubber compound around a polypropylene fabric to form sheets 0.75 in (19 mm) thick, which deflect outwards when a cage lands on the buffer assembly. Tests of early designs showed that buffers with sidewalls but with no endwalls or guide rods were unstable and prone to buckling. Subsequently, endwalls and guide rods were fitted and the walls were pre-curved outwards to prevent instability. These are referred to in this section as types C and D, being respectively 3 and 4 tier assemblies.

**Test programme**

**STATIC TESTS.** To establish their fundamental characteristics, buffers were tested in a laboratory under varying static loads. Compression and force were plotted, and a typical force/compression curve for a 4 tier buffer (type D) is shown in fig 22.2. Strain energy values were calculated from areas under the curves, and a summary of results is shown in table 22.1.

**DYNAMIC TESTS – IMPACT MACHINE.** To establish correlation between laboratory and site conditions, buffers were subjected to dynamic loading in an impact machine. Figs 22.3, 22.4 and 22.5 show the equipment used. The hammer truck of mass 4.75 ton (4.83 tonne) struck the buffers at velocities ranging from 3 to 9 ft/sec (1 to 2.8 m/sec) corresponding to a kinetic energy range of approximately 0.7 to 6.0 ft-tonf (2.1 to 18.2 kNm) for a single buffer. Fig 22.6 is a typical record of buffer reactive force and compression, and truck deceleration and velocity. Kinetic and strain energies were then calculated, and a summary of results
is in table 22.2. Figs 22.2 and 22.7 show typical dynamic force/compression curves resulting from these tests.

Figure 22.1 Typical buffer showing internal construction

Figure 22.2 Type D buffer graph of static and dynamic force/compression

9 DYNAMIC TESTS – COLLIERY. Various types, sizes and arrangements of buffers were tested under operational conditions. Figs 22.8 and 22.9 show a typical arrangement of four type D buffers. The combined cage and suspension gear mass was either 12 or 15 ton (12.2 or 15.2 tonne) to simulate empty or full man load conditions and the cage impact velocity range was 2.5 to 10 ft/sec (0.8 to 3 m/sec), corresponding to a kinetic energy range of 0.3 to 5.8 ft tonf (0.9 to 17.6 kNm) for a single buffer. Measurements were made of buffer compression and cage velocity and accelerometers mounted on the main steelwork underneath the top and bottom decks of the cage were used to measure deceleration and acceleration in the vertical and horizontal planes. Records are shown in figs 22.10 and summaries of results for types C and D buffers. Relationships between cage impact velocity and maximum deceleration are shown in figs 22.12 and 22.13. During the
latter part of the programme, changing tension in the winding rope during arrest was measured and a typical record is shown in fig 22.11. For reference purposes, tests were also made without buffers to allow the cage to land directly on the timber baulks at the pit bottom. Fig 22.14 shows a typical decelerometer record taken from these tests and table 22.5 a summary of results.

**Figure 22.3** Impact machine arranged for dynamic tests

**Figure 22.4** Oblique view of impact machine
10 COMPARISON OF IMPACT MACHINE AND COLLIERY TESTS. The test methods at the two sites were different, as shown in fig 22.15, so the deceleration results from the impact machine were adjusted to correlate with colliery test conditions. Considering that changing tension in the winding rope was not taken into account, comparison of the two sets of results shows reasonable agreement. Table 22.6 shows adjusted results for the impact machine, and fig 22.16 a comparison between these and colliery results.

Conclusions

11 Although the buffers did not fully attain the standards of the provisional performance specification, the four tier buffers, type D, nearly did, when a maximum deceleration of 2.5 g resulted from a cage impact velocity of 9 ft/sec (2.8 m/sec).
Figure 22.7 Type C buffer - Dynamic force/compression graph

Figure 22.8 Typical arrangement of type D buffers colliery tests
Figure 22.9 Typical deformation of type D buffers

Figure 22.10 Cage deformation, cage velocity and buffer compression after impact - test 47 at colliery

12. For a constant deceleration of 1 g from an impact velocity of 10 ft/sec (3 m/sec) it is necessary to have a minimum compression of 18.6 in (472 mm). However, with the design of buffer available during the tests it was only possible to achieve 12.4 in (315 mm) of compression, which was approximately 50% of the uncompressed overall height of the buffer.
13 To meet the deceleration requirements, buffers should be designed for a greater compression to height ratio, and buffers of the greatest practicable height should be utilised under mine conveyances.

14 It is desirable for a buffer to be self recovering and reusable immediately following removal of a conveyance after an impact. Generally, those tested did so, but had strong rebound characteristics such that about half of the input energy was released during recovery. Future designs should therefore be such that buffer rebound characteristics are reduced.

15 It may be necessary for some existing installations to register the position of a conveyance during mineral and materials loading. Inconsistencies in buffer performance during static tests indicate that a positive register may not be achieved readily by this means, and it is considered that this characteristic should be investigated further.
The specification adopted for buffer performance and design parameters was only provisional. A greater understanding of mechanical and physiological limitations should be established, to enable a more precise specification to be formulated.

Results of the tests are encouraging, as the buffers withstood the considerable number of impacts imposed upon them, and were capable of arresting the cage with reasonable deceleration values. However, the effects of long term use and cyclic loading should be investigated.
During arrest the rope tension decreases to zero as the cage weight is transferred from the rope to the buffers.

**Figure 22.15** Schematic illustration of test methods

**Figure 22.16** Comparison of results from colliery and impact machine tests on four-tier, type D buffers
18. Further development and experimental work, which should take account of the data and experience already gained, is required to enable a final design of buffer to be established. In the short term, tests could be made on buffers with internal guides, to investigate the performance of materials with suitable characteristics to reduce rebound. Long term development should be directed towards buffers which are inherently stable in properties and performance.

19. Change in rope tension at impact plays an important part in the mechanics of arrest of a conveyance. A complete understanding of rope effect is necessary for accurate values of retardation to be predicted and this should be further investigated.

<table>
<thead>
<tr>
<th>Test number</th>
<th>Buffer type</th>
<th>Maximum compression (governing parameter) in ft tonf</th>
<th>Total strain energy ft tonf</th>
<th>Absorbed strain energy ft tonf</th>
<th>Rebound strain energy ft tonf</th>
<th>Maximum force tonf</th>
</tr>
</thead>
<tbody>
<tr>
<td>SA 1</td>
<td>D</td>
<td>12.0</td>
<td>3.5</td>
<td>1.8</td>
<td>1.7</td>
<td>10.7</td>
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<tr>
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<td>D</td>
<td>12.0</td>
<td>3.1</td>
<td>1.4</td>
<td>1.7</td>
<td>10.3</td>
</tr>
<tr>
<td>3</td>
<td>D</td>
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<td>2.8</td>
<td>1.3</td>
<td>1.5</td>
<td>10.0</td>
</tr>
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<td>1.9</td>
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<td>10.3</td>
</tr>
<tr>
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<td>D</td>
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<td>1.3</td>
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</tr>
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<td>1.2</td>
<td>8.9</td>
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<td>0.6</td>
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<td>3.6</td>
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<td>0.8</td>
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<td>0.8</td>
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</table>
### Table 22.2 Impact machine test results with buffers

<table>
<thead>
<tr>
<th>Test number</th>
<th>Buffer type</th>
<th>Maximum compression (governing parameter) in Total strain energy ft tonf</th>
<th>Absorbed strain energy ft tonf</th>
<th>Rebound strain energy ft tonf</th>
<th>Maximum force tonf</th>
</tr>
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<tr>
<td></td>
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<tr>
<td>SG 1</td>
<td></td>
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<td>1.5</td>
<td>0.7</td>
<td>0.8</td>
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<tr>
<td>2</td>
<td></td>
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<td>0.9</td>
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<td>3</td>
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</table>

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### Table 22.3 Colliery dynamic tests 45 to 55 buffers

<table>
<thead>
<tr>
<th>Date</th>
<th>Test No</th>
<th>Type</th>
<th>Cage condition</th>
<th>Impact velocity (ft/sec)</th>
<th>Upper deck Vertical Max decel. (g)</th>
<th>Upper deck Vertical Max rebound (g)</th>
<th>Lower deck Vertical Max decel. (g)</th>
<th>Lower deck Vertical Max rebound (g)</th>
<th>Average decel. (g)</th>
<th>Time at 1st arrest above 2.5 g (sec)</th>
<th>First arrest (in)</th>
<th>Final arrest (in)</th>
<th>Remarks</th>
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<td>45</td>
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<td>E</td>
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<td>0.12</td>
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<td>7½</td>
<td>3½</td>
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<td></td>
<td>53</td>
<td>FML</td>
<td>8.7</td>
<td>2.1</td>
<td>0.6</td>
<td>3.0</td>
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<td>2.1</td>
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<td>8¼</td>
<td>3½</td>
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<td>54</td>
<td>FML</td>
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<td>9¼</td>
<td>-</td>
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<td>0.07</td>
<td>0.10</td>
<td>14</td>
<td>8½</td>
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</table>

Cage condition
- E = Empty
- FML = Full Man Load

**Notes:**
- 16 As measured by Optical Displacement Device
- 17, 18 From Lower Deck Vertical Accelerometer
### Table 22.4 Colliery dynamic tests 57 to 71 with buffers

<table>
<thead>
<tr>
<th>Date</th>
<th>Test No</th>
<th>Type</th>
<th>Cage condition</th>
<th>Impact velocity (ft/sec)</th>
<th>Max rebound (g)</th>
<th>Max decel (g)</th>
<th>Max rebound (g)</th>
<th>Max decel (g)</th>
<th>Average decel (g)</th>
<th>Time to 2.5 g (sec)</th>
<th>Time to 1st arrest (sec)</th>
<th>First arrest (in)</th>
<th>Final (in)</th>
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<td>E</td>
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<td>0</td>
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<td>7</td>
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<td>1.3</td>
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<td>0</td>
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<td>-</td>
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<td>0.6</td>
<td>0</td>
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<td>3½</td>
<td>5½</td>
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<td>71</td>
<td>FML</td>
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<td>-</td>
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<td>1.4</td>
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</tr>
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<td>FML</td>
<td>Top Hats</td>
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<td>0</td>
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<td>FML</td>
<td>Top Hats</td>
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<td>0.17</td>
<td>4</td>
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<table>
<thead>
<tr>
<th>Cage condition</th>
<th>E = Empty</th>
</tr>
</thead>
<tbody>
<tr>
<td>FML = Full Man Load</td>
<td></td>
</tr>
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</table>

18 As measured by Optical Displacement Device
19, 20 From Lower Deck Vertical Accelerometer
### Table 22.5 Colliery dynamic tests. Cage landing directly on baulks

<table>
<thead>
<tr>
<th>Date</th>
<th>Test No</th>
<th>Buffer type</th>
<th>Cage condition</th>
<th>Impact velocity (ft/sec)</th>
<th>Maximum deceleration (g)</th>
<th>Max rebound (g)</th>
<th>Average deceleration (g)</th>
<th>Time period above 2½ g cage deceleration (sec)</th>
<th>Ascending cage deceleration</th>
<th>Remarks</th>
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<tbody>
<tr>
<td>13.11.74</td>
<td>1</td>
<td>None</td>
<td>E</td>
<td>3.5</td>
<td>5.9</td>
<td>0.7</td>
<td>2.9</td>
<td>0.02</td>
<td>-</td>
<td>-</td>
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<td>72</td>
<td>None</td>
<td>FML</td>
<td>2.5</td>
<td>4.2</td>
<td>0.4</td>
<td>2.1</td>
<td>0.02</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
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<td>73</td>
<td>None</td>
<td>FML</td>
<td>8.0</td>
<td>1.0</td>
<td>4.0</td>
<td>0.03</td>
<td>0.5</td>
<td>Deceleration exceeded calibrated range of instrumentation</td>
<td></td>
</tr>
<tr>
<td>11.12.74</td>
<td>74</td>
<td>None</td>
<td>FML</td>
<td>14.0</td>
<td>-</td>
<td>7.0</td>
<td>-</td>
<td>0.5</td>
<td>Calibration range changed to accept decelerated induced</td>
<td></td>
</tr>
<tr>
<td>11.12.74</td>
<td>75</td>
<td>None</td>
<td>FML</td>
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<td>8.0</td>
<td>0.03</td>
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<td>Calibration range changed to accept decelerated induced</td>
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<tr>
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<td>FML</td>
<td>3.1</td>
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<td>2.5</td>
<td>0.02</td>
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**Cage condition**

E = Empty  
FML = Full Man Load

### Table 22.6 Impact machine test results with buffers – adjusted to colliery conditions

<table>
<thead>
<tr>
<th>Test number</th>
<th>Buffer type</th>
<th>Total strain energy ft tonf</th>
<th>Input velocity ft/sec</th>
<th>Maximum deceleration g</th>
<th>Mean deceleration g</th>
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<td>dA 1</td>
<td>D</td>
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<td>4.6</td>
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<tr>
<td>2</td>
<td>D</td>
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<td>6.0</td>
<td>1.4</td>
<td>1.0</td>
</tr>
<tr>
<td>3</td>
<td>D</td>
<td>3.2</td>
<td>7.4</td>
<td>1.7</td>
<td>1.3</td>
</tr>
<tr>
<td>4</td>
<td>D</td>
<td>4.1</td>
<td>8.4</td>
<td>2.0</td>
<td>1.4</td>
</tr>
<tr>
<td>5</td>
<td>D</td>
<td>5.5</td>
<td>9.7</td>
<td>3.0</td>
<td>1.5</td>
</tr>
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<td>6</td>
<td>D</td>
<td>5.4</td>
<td>9.6</td>
<td>3.2</td>
<td>1.5</td>
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<tr>
<td>dB 1</td>
<td>D</td>
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<td>4.8</td>
<td>1.0</td>
<td>0.8</td>
</tr>
<tr>
<td>2</td>
<td>D</td>
<td>2.2</td>
<td>6.1</td>
<td>1.3</td>
<td>1.0</td>
</tr>
<tr>
<td>3</td>
<td>D</td>
<td>3.4</td>
<td>7.6</td>
<td>1.7</td>
<td>1.0</td>
</tr>
<tr>
<td>4</td>
<td>D</td>
<td>4.1</td>
<td>8.3</td>
<td>2.3</td>
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<td>5</td>
<td>D</td>
<td>4.7</td>
<td>9.0</td>
<td>3.4</td>
<td>1.5</td>
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<tr>
<td>dG 4</td>
<td>C</td>
<td>0.7</td>
<td>3.6</td>
<td>1.8</td>
<td>1.3</td>
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<tr>
<td>5</td>
<td>C</td>
<td>1.3</td>
<td>4.8</td>
<td>1.9</td>
<td>1.3</td>
</tr>
<tr>
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<td>C</td>
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<td>6.2</td>
<td>2.0</td>
<td>1.8</td>
</tr>
<tr>
<td>7</td>
<td>C</td>
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<td>7.2</td>
<td>2.5</td>
<td>2.0</td>
</tr>
<tr>
<td>8</td>
<td>C</td>
<td>3.6</td>
<td>7.8</td>
<td>3.1</td>
<td>2.0</td>
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<tr>
<td>9</td>
<td>C</td>
<td>4.1</td>
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<td>9.3</td>
<td>4.3</td>
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This is a web-friendly version of Safe manriding in mines: First Report of the National Committee for Safety of Manriding in shafts and Unwalkable Outlets, originally produced by HM Inspectorate of Mines.
<table>
<thead>
<tr>
<th>Test number</th>
<th>Buffer type</th>
<th>Total strain energy ft tonf</th>
<th>Input velocity ft/sec</th>
<th>Maximum deceleration g</th>
<th>Mean deceleration g</th>
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<td>4.5</td>
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<td>4</td>
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<td>2.8</td>
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<td>C</td>
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<td>3.8</td>
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<td>5.2</td>
<td>2.3</td>
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Headframe and shaft equipment

23 Typical override circuit associated with headframe ultimate limit switches

1 A typical circuit to satisfy the requirements of paragraph 64 of Part 1A is described below.

2 When long materials have to be lowered down a shaft, at many winding installations loading of this material requires the conveyance to be raised beyond the point at which an overwind switch on the automatic contrivance is operated, and in some instances beyond the point at which the headframe ultimate limit switch is operated. Further, having provided headframe ultimate limit switches to increase safety, then proper means should be provided to enable each switch to be operated by the corresponding conveyance for test purposes and then allow the conveyance to be backed out.

3 Part 1A of the Report recommends that a self-return lockable switch is provided for the above manoeuvring and testing. A typical circuit for use with a self-return lockable switch is shown in fig 23.1.

Description of operation

4 The man/coal selection lever is placed in the mineral winding position, closing contacts MSS₁ and MSS₂. These contacts permit the use of the override circuitry and ensure that man indication is not shown at the various shaft levels whilst the contacts MSS₁ and MSS₂ remain closed.

5 A key, normally in the possession of an authorised person, is inserted into the manoeuvring switch S which is of the self return lockable type and situated at a convenient position at the surface landing.

6 To override only the automatic contrivance overwind protection in the forward direction, switch S is turned to position F₁. This introduces the 4 ft/sec (1.2 m/sec) overspeed switch contacts into safety circuit 1a to ensure that any manoeuvring above bank level is carried out at a speed less than 4 ft/sec. The forward overwind switch FOW is thus shorted out by contacts, S₁, FHMLS, and MSS₁, and allows the left hand conveyance to be raised. Manoeuvring can then take place up to the headframe ultimate limit switch FHULS.

7 Operation of the switch S to position F₂ shorts out the forward headframe ultimate limit switch FHULS by contacts S₂ and MSS₂. This allows the conveyance to be raised further, still at the reduced speed of less than 4 ft/sec, until the forward headframe manoeuvring limit switch FHMLS is reached. Any further upward movement of the conveyance will operate limit switch FHMLS and trip out the safety circuit 1a.

8 In order to recover the situation, the winding engineman has to use the well established backing out facility to lower the conveyance. At the same time the switch S must be held at position F₁. When the conveyance has returned to the normal level, manoeuvring switch S can be returned to the off position and the key can then be removed. Thus the protection provided by the contrivance overwind switch and the headframe ultimate limit switch is restored.
Figure 23.1 Typical override circuit associated with headframe ultimate limit switches

9 Switch positions R₁ and R₂ can be used for manoeuvring the reverse conveyance above bank level.

10 The circuit can also be used when the conveyances are used to test the headframe limit switches for correct operation.

11 Indication in the winding engine house should show the position of switch S, indication at bank and shaft levels should show ‘Materials being handled’.
24 Technical aspects of providing headframe catches

1 Paragraph 67, of Part 1A refers to the technical aspects of providing headframe catches and paragraph 68 recommends that catches or equivalent devices be provided in the headframe of every drum winding installation to prevent conveyances from falling back an excessive distance after detachment. Regulations already require catches to be provided on friction winding installations.

2 Catches should be designed to support the conveyances, taking account of the actual fall back which should not exceed 9 in (0.23 m). Catches should be so positioned in the headframe, that a conveyance would engage them approximately 2 ft (0.61 m) before detaching, with maximum adjustment length in the suspension gear. The catches were practicable should be continuous for the remaining upward travel of the conveyance and be arranged to allow egress from the conveyance. Where catches have to be fitted at the ends of the conveyance and prevent reasonable egress, the design should readily permit their removal after supporting the conveyance by other means. Where this is not practicable, instead of making a section of the continuous catches removable, a shorter set of catches could be provided if this would assist egress. In this latter case, an additional safeguard should ensure that, with the 50% braking philosophy outlined in Part 1A, paragraph 3, an ascending conveyance should not reach the position of detachment.

25 Requirements for a kep interlocking and indication system

1 Paragraph 72 of Part 1A, refers to an interlocking arrangement between keps and winding engine. Where keps have to be retained for purposes other than man winding, facilities to indicate that they are clear, or have been reinserted, should satisfy the following requirements:

(1) Before commencement of manriding the banksman, and the onsetter, where appropriate should lock the keps in the clear position.

(2) A ‘Clear’ signal automatically actuated by the keps should be displayed to the winding engineman to show that the keps are fully retracted. The signal should be interlocked with the Men/Coal selection lever and the brake locking device in such a way that this device is actuated to lock the brakes on when the Men/Coal selection lever is in the Men position and the keps are not in the clear position. The winding engineman should not place the Men/Coal selection lever in the Men position until he has first received the keps Clear signal.

(3) An audible warning should be given to the winding engineman should the keps Clear signal be cancelled during a manwind.

(4) An ‘Under’ signal automatically actuated by the keps should be displayed to the winding engineman to show that the keps are not fully retracted.

(5) As far as is practicable the system for visible and/or audible warning should be fail-safe.

2 Each winding engine not fitted with an automatic contrivance, or with an automatic contrivance permanently set for man winding, should be provided with a Men/Coal changeover switch. This switch should be operated and interlocked in the same manner as the Men Coal selection lever referred to previously in paragraph 2 above.
3 Whenever practicable the device(s) provided to actuate a clear signal automatically, should detect that each arm or shoe of the keps is in the fully retracted position before a Clear signal is displayed. The Clear signal should be cancelled and an Under signal automatically actuated whenever the keps are not in the fully retracted position.

4 Where it is not practicable to position a device to detect that each arm or shoe of the keps is in the fully retracted position, then a device actuated by the operating mechanism of the keps, positioned as near as possible to the arms or shoes, may be employed.

5 With either arrangement the interconnecting cables should have individually screened cores and the circuit should be protected against earth fault.

26 Operational requirements for a slack rope protection system

The operational requirements for a slack rope protection system, referred to in paragraph 81 of Part 1A, are listed below:

(1) The system should indicate creation of slack rope at any part of a wind.

(2) The system should be capable of initiating a trip when the amount of slack rope exceeds 6 inches (150 mm) at or near bank, pit bottom or an inset, and preferably throughout a wind.

(3) Accuracy and reliability should not be affected significantly by rope stretch, bounce, shocks to the conveyance or slack rope produced during normal winding operations.

(4) Maintenance requirements should be minimal.

(5) If batteries are used, the load imposed on them should be such that the time between replacements should be as long as possible, but not less than one week, consistent with restrictions on weight and size.

(6) The system should fail to safety. Alternatively, any fault resulting in inaccuracy of non-operation should be self-revealing.

(7) The system should be certificated for use in flammable atmospheres.

(8) Alarm and trip facilities should be provided.

(9) There should be indication of the direction of travel required to retrieve slack rope.

(10) The system should have built-in test facilities for checking that it is in order.

27 Typical circuit for detection of a false signal

1 Reference is made in paragraph 88 of Part 1A to the provision of indication to a winding engineman that a signal received by him is false. Fig 27.1 shows a system in schematic form.

2 The false signal facility provides a means of determining whether a signal has originated from a particular level or has occurred due to a fault.
Table 27.1 Circuit diagram for detection of false signals

Operation

3 Operation is as follows:

Consider Level 5 signal key.

If the positive of the supply is applied, due to a fault, to the level 5 L relay, it will also be applied to FE relay (False Signal Relay Group) when the signal key is in the normal position. FE relay is then held in by current from the positive of the supply via the reset key and FE1; through FE2 the false signal indicator in the winding engine house is illuminated.

The false signal indication is cleared by operation of the reset key, which releases FE.

Circuit operation for the other levels is as that for Level 5. In fig 27.1, Level 1 shows circuitry when differing positions are required for men and coal. Level 2 shows circuitry required for right hand and left hand signalling facilities.

Test facilities

4 The test push buttons when operated apply a positive supply to the respective L relay and false signal relays, thereby providing a means of checking that the false signal equipment is in order.
28 Typical circuit for detection of an incomplete signal

1 Paragraph 88 of Part 1A refers to the provision of indication to the winding engineman that a signal received by him is incomplete. Fig 28.1 shows a system in schematic form. The incomplete signal facility provides a means of visually indicating to the winding engineman that only one action signal has been received, i.e., from either banksman or onsetter but not from both. To simplify presentation, the circuit diagram is restricted to the case where winding operations take place between pit and bank and pit bottom, the banksman is required to give a lower or lower steadily signal, and the onsetter a raise or raise steadily signal.

![Figure 28.1 Circuit diagram for indication of an incomplete signal](image)

**Figure 28.1** Circuit diagram for indication of an incomplete signal

**Operation**

2 Operation is as follows:

The onsetter signals Raise 1 and the positive of the supply is connected from Level 4 relay group via the first contact on the uni-selector to relay RD.

Relay contact RD1 prepares a circuit for relay BR.

Relay contact RD2 connects the positive of the supply via relay contact BR4 to
illuminate the Stop Signal Incomplete indicator.

The banksman signals Lower 2 and the positive of the supply is connected from Level 1 relay group via the second contact on the uni-selector to relay LA.

Relay contact LA2 has no effect since relay contact RD2 is operated first and is in parallel with it.

Relay contact LA3 illuminates the normal Lower Indicator.

Relay BR will now be energised via relay contacts LA1 and RD1.

Relay contact BR4 breaks the supply to the Stop Signal Incomplete indicator.

Relay contact BR3 provides a holding circuit for relay BR via the cancel circuit which releases relay BR at the end of a wind.

Relays RD and LA release as a wind commences and relay BR releases at the end of the wind.

Relay contacts BR1 and BR2 are available for inclusion in the winding engine brake control system.

**Facilities for first entry down a mine**

3 To enable the first person to be lowered into a mine, such as an onsetter, it is necessary to override the incomplete signal facility. To achieve this, a switch is provided which operates relay BR and an indication Incomplete Signal Over-ridden is illuminated in the winding engine house. Preferably, the override facility should be cancelled automatically on receipt of the first signal transmitted from the appropriate level. This can be achieved by replacing the override switch with a relay and push button so that operation of the push button energises this relay which completes the override circuit and illuminates the Incomplete Signal Over-ridden Lamp. The relay is de-energised by contacts on the appropriate level relay when the first signal is sent from that level.
Maintenance, testing and training

29 Procedure for reviewing winding engine maintenance schemes

Introduction

1 In Part 1A, paragraph 104.2, it is recommended that a standard procedure is adopted for reviewing winding engine maintenance schemes and that this procedure be applied to every installation. The purpose of such a review is to ensure that work instructions and check lists forming the scheme of maintenance include all examinations, tests and maintenance essential for safe and efficient working of the particular winding engine, and that the nature of the work to be done is so specified that it can be clearly understood. To assist the review, model maintenance information manuals have been prepared for three different types of winding engine so that existing maintenance schemes can be brought into line with these model manuals. A maintenance information manual should be prepared for each winding engine and be the primary reference document for winding engine maintenance and include details of any changes to the duty or equipment which have occurred during the life of the winding engine. The manual should thereafter be kept up to date.

Review of scheme and preparation of manual

2 The review should be undertaken using the following four main headings and, a maintenance information manual subsequently prepared from it with the following schedule of contents.

Winding engine specification

3 This portion of the manual should detail the cardinal operating and design information for the winding engine in three parts:

(1) OPERATIONAL TECHNICAL PARTICULARS. These include operational information such as depth of wind, weight of cages, payloads etc for the full range of duties including manriding and any special duties for which the equipment is designed. Where available, duty cycle diagrams should be incorporated.

(2) MECHANICAL LIST AND TECHNICAL PARTICULARS. The mechanical equipment should be listed in units which can reasonably be covered by one check list and for which there may be available a manufacturer’s instruction book. The list forms an index to detailed maintenance instructions included in the portion of the manual headed equipment maintenance (paragraph 6 of this section) and elsewhere in the manual.

(3) ELECTRICAL EQUIPMENT LIST AND TECHNICAL PARTICULARS. This should list electrical equipment on the same basis as that for the mechanical equipment.

Winding engine operating control and safety systems

4 The functions of the operating, control and safety equipment should be described under this heading. In many instances it will only be necessary to cross-reference to existing manuals supplied by manufacturers. Where suitable information is not available this portion of the manual should include the following:
(1) MANUAL OPERATION OF THE WINDING ENGINE. This should be a simple description of the operation of controls and of the instruments used by the winding engineman together with details of special precautions, safety aspects, and routine checks and simple maintenance which he is required to carry out. This description can form a section of the winding engineman’s operating manual referred to in paragraphs 128 and 130.5 of Part 1A.

(2) WINDING ENGINE CONTROL SYSTEM. This should be an engineering description of the winding engine control arrangement insofar as is necessary to ensure that the function of the various items of equipment can be understood in relation to the system as a whole.

(3) WINDING ENGINE SAFETY SYSTEM. It is important that equipment comprising the safety system be identified as a whole, and that principles of operation and functions of each item of equipment be clearly stated.

Performance maintenance

5 Details of all tests to be carried out to check satisfactory performance of control and safety systems should be incorporated in this portion of the manual. Routine brake performance checks and statutory testing of automatic contrivances and safety systems should be included.

Equipment maintenance

6 This portion of the manual should be in two parts: mechanical equipment and electrical equipment. Each part should cover the equipment listed in, and in the same order as, the section headed winding engine specification (paragraph 3 of this section). Maintenance tasks for each item of equipment should be specified for each unit to form check lists and the intervals between tasks stated. Whenever a check requires explanation, or where a task may result in some work being done which requires detailed explanation, then this should be included either in this portion of the manual or in an appendix. Information on settings, adjustments, instrument headings, wear tolerances etc should be included either in this part or in appendices.

General considerations

7 When carrying out the review consideration should be given to the following.

Lubrication arrangements

8 Existing lubrication arrangements should be carefully examined and any arrangements considered unsatisfactory should be referred to the Chief Engineer. A lubrication schedule should form part of the scheme of maintenance.

Routine non-destructive testing

9 The extent to which routine non-destructive testing is to be carried out should be scheduled. The components to be tested, the method of non-destructive testing and the frequency of testing should be listed.

Environment

10 If necessary, steps should be taken to prevent the contamination of brake linings and paths or any other vital parts of the safety equipment by oil, grease, condensation or rain water. Drum pits should not be allowed to become so
contaminated with grease as to prevent effective examination of brake anchor brackets and beams. If necessary special provisions should be made to ensure adequate and safe access to equipment requiring examination and maintenance. Adequate lighting should be provided to enable examinations to be effectively carried out.

**Guards**

11 Ensure that sufficient suitable guards are provided, particularly that they fit properly and are well secured.

### 30 Schedule of maintenance administrative procedures, documentation, duties and responsibilities of personnel

1 In Part 1A, paragraph 106, reference is made to a description of a maintenance scheme suitable for application to winding engines, and it is recommended (paragraph 107) that each manager’s scheme for the mine incorporates the principles embodied in the procedures and documentation associated with that scheme. The procedures and documents described in this section are among those to be brought into use within the National Coal Board. They are based on those in use but detailed modifications have been made to increase their flexibility in order to raise the standard of reporting, and simplify the task of scrutinising reports. New style headings have been designed for forms to remind persons who use them of the legal requirements of the manager’s scheme. It should be noted that in addition to the documentation described below, regulations require the results of certain examinations and tests to be entered on prescribed M & Q Forms.

**General requirements**

2 Each mine manager is responsible for setting up a manager’s scheme for the mine in accordance with the Coal and Other Mines (Mechanics and Electricians) Regulations 1965. The object of such a scheme is to ensure an efficient standard of maintenance to comply with the above regulations and to suit the conditions which exist at the mine.

3 Each manager’s scheme for the mine, setting out the maintenance tasks as identified by check lists, and the frequencies of these tasks, should be documented in a standard manner on Form ME1. This schedules instructions from the manager to the mine mechanical and electrical engineers, defining their duties in these respects under Part III of the Coal and Other Mines (Mechanics and Electricians) Regulations 1965.

4 The frequencies of certain examinations specified in particular regulations (eg Steam Boilers Regulations; Shaft, Outlets and Roads Regulations) cannot be varied by the mine manager.

For other examinations included in the manager’s scheme for the mine, it is recommended that the frequencies be planned with tolerances to allow some flexibility in operation of scheduled maintenance. Recommended intervals and tolerances, which should be confirmed in the manager’s instructions to the mine mechanical and electrical engineers, are as follows.

**WEEKLY (W)**

Fifty-two times a year at approximately 7 day intervals.

---

3 ME forms referred to may be found at the end of this section.
MONTHLY (M)
Thirteen times a year at intervals of not less than 3 weeks and not greater than 5 weeks from the week when the last such examination was carried out.

QUARTERLY (Q)
Four times a year at intervals of not less than 11 weeks and not greater than 15 weeks from the week when the last such examination was carried out.

HALF ANNUAL (½A)
Twice a year at intervals of not less than 24 weeks and not greater than 28 weeks from the week when the last such examination was carried out.

ANNUAL (A)
Once a year at intervals of not less than 48 weeks and not greater than 56 weeks from the last such examination. (It is appreciated that certain annual inspections are best made during mine holiday periods which may not coincide with the suggested period of tolerance; but this tolerance should be observed wherever possible).

Other intervals in excess of one year should be decided on a local basis.

5 The basic documentation detailing the manager’s scheme for the mine and associated procedures is in the following paragraphs.

Form ME1 maintenance schedule

6 This schedule details the frequencies of the various types of maintenance tasks to be carried out as identified by check lists. The form is arranged so that plant can be listed by types, eg gate end boxes, compressors, haulages etc or by duty. The same type of plant can be included more than once where different locations and operating circumstances affect the frequency of maintenance tasks. If required each item of plant can be listed separately but the preferred arrangement is to list plant by type or duties.

Form ME1/A maintenance schedule amendment sheet

7 This is a schedule to supplement form ME1 designed to accommodate up to 12 amendments. Its purpose is to allow form ME1 to be conveniently updated without having completely to re-write the ME1 schedule. It is recommended however that the number of amendments on forms ME1/A should be limited to say 20, after which a new form ME1 should be prepared to include all known amendments.

Form ME2 plant specification

8 The plant specification card together with the plant history card (form ME3) comprise the basic record for an item of plant. In the National Coal Board, for those items of equipment administered by an area plant pool, the specifications card should be prepared as part of area plant pool procedures. Ample room is afforded on the card for inclusion of technical or other data additional to basic specification information recorded by an area plant pool. For items of equipment not administered by an area plant pool, a card should be prepared at the mine and the specification incorporated on the left hand side together with any information on purchase price, maker’s plant number etc which may be available. Additional technical or other data can be incorporated on the right hand side of the card. When an item of plant is transferred from a mine, the plant specification and plant history cards should be sent to the new location. When an item of plant is to be repaired at a central workshop these record cards should be sent to the workshop.
where details of any modifications carried out should be recorded on the 
specification card and a brief statement of repairs effected made on the history 
card. The same record cards should then be used again at the mine where the 
plant is next employed. In the case of an item of plant administered by an area 
plant pool, all such movements of record cards should be routed via the area plant 
pool manager.

**Form ME 3 plant history card**

9 This card should record all significant events relevant to the engineering history 
of the plant which mine engineers require. It should also include details of repairs 
and renewals carried out away from the mine. The column headed Defect Code is 
intended for the possible future adoption of a method of coding so that particular 
types of defect and frequency with which they occur may easily be identified. A 
planning scale is included on this card as an alternative to that on the specification 
card to allow either to be the facing card in storage cabinets.

**Form ME4 routine work instruction and reports**

10 These forms ME4(E) and ME4(M), for electrical and mechanical reports 
respectively, are intended to cover one week’s daily and weekly maintenance tasks 
for one man. Facility is provided for the form to accommodate more than one 
craftsman’s signature during any one day; the purpose is to allow tasks not carried 
out by the craftsman to whom the list was issued to be performed by another 
craftsman possibly on a different shift. The periodic tasks for one week are 
contained on separate forms ME4(E)P and ME4(M)P respectively. Each periodic 
form is designed to accommodate a written report, including the results of tests, 
and each form can be used by a number of craftsmen since each task is signed for 
separately. When a periodic form is used, there is no need for a report to be also 
made on an ME5 shift report form. In addition to the forms which accommodate 
routine tasks, form ME4(NR) Non-routine Work Instruction and Report is designed 
for use by craftsmen and others who are employed on non-routine tasks, 
eg installations. Since the bottom section of this form has space for a report, the 
use of form ME5 is unnecessary in this circumstance. It would be necessary 
however, if the man did routine work additional to that listed on ME4(NR).

**Form ME5 shift report**

11 A shift report should be submitted at the end of each shift by each man who 
has carried out a routine maintenance task. The report should include details of 
breakdowns and defects, including those discovered during routine maintenance, 
details of any repairs, spares usage, and other relevant information such as plant 
movement required to be brought to the notice of mine engineers or included on 
the plant history card.

**Form ME6 defect action sheet**

12 This form, which has a distinctive colour, should be raised when consequent 
action has to be taken upon a defect not corrected at the time and which is 
identified on a shift report form ME5 or non-routine work instructions and report 
form ME4(NR) or periodic examination form ME4P. The forms should be prepared 
duplicate, the top copy issued to the person detailed to remedy the defect and 
the carbon copy retained in the office. On the return of the completed top copy to 
the office, the carbon copy should be destroyed, necessary action initiated and the 
top copy filed so that a check of forms issued can be kept. This procedure is 
 supplementary to the statutory requirement to record defects in the appropriate 
M & Q books numbers 267 and 268.
Form ME7 examinations in final week of tolerance and application for temporary amendments to the managers scheme for the mine

13 No amendments to the scheme should be made without the manager’s approval. The adoption of tolerances to allow flexibility in the operation of scheduled maintenance where the frequency is not specified in regulations, should assist mine engineers to cater for normal variations in resources and circumstances. All tasks beginning their final week of tolerance should be entered by the planned maintenance clerk on the appropriate side of form ME7. The form should then be passed to the appropriate mine engineer who should decide on action. Exceptional circumstances may arise when it becomes clear that with facilities currently available a periodic task is not likely to be completed within the period of tolerance. In such cases, the mine engineer should appraise the situation, and where he is satisfied with the condition of the equipment, make application to the manager for temporary amendment to the scheme by entering the task on the other side of form ME7. The mine manager, on receipt of form ME7, is required either to take special action to see that the work is carried out within the initial period of tolerance or agree to the proposed amendment if he is satisfied with the engineer’s assessment.

Form ME8 record of electrical tests

14 For electrical equipment form ME8 is provided to give a continuous record of test results. Similar forms can be prepared to suit local requirements to give a continuous record of mechanical tests.

Duties and responsibilities

<table>
<thead>
<tr>
<th>Action</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PLANT RECORD CARDS (ME2 AND ME3)</strong></td>
<td></td>
</tr>
<tr>
<td>The main maintenance clerk should</td>
<td></td>
</tr>
<tr>
<td>15 Complete a plant specification card (ME2) and a plant history card (ME3) for each item of plant as new records are required.</td>
<td>For equipment controlled by area plant pool, the specification card will be completed as part of the area plant pool procedure and issued to the maintenance clerk for the mine. For certain items of plant, it will also be necessary to complete a record of tests.</td>
</tr>
<tr>
<td>16 File the cards in cabinets, in walking order of the district of the mine or by types of plant.</td>
<td>The cards will then constitute a complete inventory of all plant at the mine.</td>
</tr>
<tr>
<td>17 Attach coloured signals to the timescale on each ME 2 to denote the maintenance tasks required to be carried out as set out in the schedule of tasks (ME 1).</td>
<td>The schedule of maintenance tasks may either be rigid under which each periodic task is indicated by a separate signal, or flexible where one signal is used and is progressively moved along the planning scale as tasks are completed.</td>
</tr>
<tr>
<td>18 In conjunction with the mine engineers, ensure that the schedule of maintenance tasks (as displayed by the signals) presents an evenly spread work load and meets the requirements of the mine engineers and of the manager’s scheme for the mine.</td>
<td></td>
</tr>
<tr>
<td>19 List all items of plant due for daily and weekly inspections on routine work instruction and report forms (ME4(E) and ME4(M)).</td>
<td>The list should be backed with hectographic carbon or be prepared in such a way that it is suitable for photocopying. The list then becomes a master from which copies can be obtained.</td>
</tr>
<tr>
<td>Action</td>
<td>Remarks</td>
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</tr>
<tr>
<td><strong>PREPARATION AND COMPLETION OF WORK INSTRUCTION AND REPORT FORMS (ME4)</strong>&lt;br&gt;The main maintenance clerk should</td>
<td></td>
</tr>
<tr>
<td>20 Check each week that the items entered on the master lists coincide with the plant in the district as shown by the filed plant record cards.</td>
<td>Paragraph 19 refers. This comparison can only be made if plant record cards are filed only in walking order. Paragraph 16 refers.</td>
</tr>
<tr>
<td>21 If plant in a district has changed, amend the master list accordingly.</td>
<td></td>
</tr>
<tr>
<td>22 Prepare work instruction and report forms (ME4(E) and ME4(M)) by making one copy of each master.</td>
<td>Where plant movements are rare, it may be advantageous to prepare more than one copy at a time. However, it is essential that copies should be checked each week to ensure accuracy. Paragraph 20 refers.</td>
</tr>
<tr>
<td>23 Collate the copies of the work instruction and report forms into district sets; and enter the week commencing date, the week number and the list number on each form.</td>
<td></td>
</tr>
<tr>
<td>24 Check the signals on the plant record cards, and enter periodic tasks due during the week on forms ME4(E)P as appropriate. Care must be taken to ensure that, when instructions for periodic tasks are issued, any weekly task on the same item is deleted. The type of examination be indicated by the usual code and, in the adjacent space, the number of the week by which the task must be completed before the approved tolerance is exceeded. Ring in red any weekly task not completed in the previous week and any periodic task in its final week of tolerance. Advise the mine engineers of statutory tasks without tolerances about to become due. The period of pre-notice to be given will be agreed with the mine engineer.</td>
<td></td>
</tr>
<tr>
<td>25 Insert the work instruction and report forms, any defect action sheets (ME6) and a blank shift report (ME5) into the appropriate binders and pass them to the mine engineer.</td>
<td></td>
</tr>
<tr>
<td><strong>The mine engineer, or a person nominated by him, should</strong></td>
<td></td>
</tr>
<tr>
<td>26 Examine the binders and enter the name or title of the person, responsible for carrying out the tasks, in the appropriate box of the work instruction and report forms.</td>
<td>This can be done by the mine maintenance clerk on instructions from the mine engineer.</td>
</tr>
<tr>
<td>27 Issue the binders containing the work instruction and report forms to the craftsmen.</td>
<td>This can usually best be done by placing the binders in special racks for collection by craftsmen.</td>
</tr>
<tr>
<td><strong>Each craftsman should</strong></td>
<td></td>
</tr>
<tr>
<td>28 Take his binder and check lists with him, and carry out the tasks as indicated by the relevant letter shown against each item of plant and as defined in the check list book.</td>
<td></td>
</tr>
<tr>
<td>Action</td>
<td>Remarks</td>
</tr>
<tr>
<td>--------</td>
<td>---------</td>
</tr>
<tr>
<td>29</td>
<td>Check details of plant examined and amend the plant numbers or any detail on the work instruction and report forms where they differ from those shown.</td>
</tr>
<tr>
<td>30</td>
<td>Complete the relevant part of each form as each maintenance task is done.</td>
</tr>
<tr>
<td>31</td>
<td>Undertake any special work noted on defect action sheets (ME6) included in his binder; and complete the necessary entries on the sheet. Paragraph 25 refers.</td>
</tr>
<tr>
<td>32</td>
<td>At the end of the shift, initial the space at the foot of the appropriate daily column of ME4(E) or ME4(M). Complete shift report (ME5).</td>
</tr>
<tr>
<td>33</td>
<td>Return his binder to the mine maintenance clerk at the end of the shift. This can be done by replacing the binders in special racks (see paragraph 27) or by any other local arrangement.</td>
</tr>
</tbody>
</table>

**ACTION TO BE TAKEN ON COMPLETED WORK INSTRUCTIONS AND REPORT FORMS (ME4), SHIFT REPORTS (ME5) AND DEFECT ACTION SHEETS (ME6)**

The mine maintenance clerk should:

<table>
<thead>
<tr>
<th>Action</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>34</td>
<td>Collect completed binders from craftsmen each day and check that all binders are accounted for.</td>
</tr>
<tr>
<td>35</td>
<td>Pass the completed binders each day to the mine engineer or to a person nominated by him and inform him if any binders are missing.</td>
</tr>
</tbody>
</table>

The mine engineer, or the person nominated by him, should:

<table>
<thead>
<tr>
<th>Action</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>36</td>
<td>Scrutinise the work instruction and report forms and satisfy himself that the maintenance programme is being kept up to date. If necessary, to ensure completion of the inspection programme, the work instruction and report forms should be reallocated to a craftsman on a subsequent shift.</td>
</tr>
<tr>
<td>37</td>
<td>Scrutinise all shift reports (ME5) and any completed defect action sheets (ME6). Mark any item he wishes to be recorded on the plant history cards (ME3) or on appropriate M &amp; Q forms and indicate if he wishes a defect action sheet (ME6) to be prepared. Where a reported defect involves aspects of safe working which fall within the sphere of responsibility of another discipline, the relevant section of the report should be copied and passed to the engineer or official concerned for appropriate action, and a note that this has been done should be made on the shift report.</td>
</tr>
<tr>
<td>38</td>
<td>Pass the binders back to the mine maintenance clerk.</td>
</tr>
</tbody>
</table>

The mine maintenance clerk should:

<table>
<thead>
<tr>
<th>Action</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>39</td>
<td>Extract the completed shift reports (ME5) from each binder and insert a fresh copy.</td>
</tr>
<tr>
<td>Action</td>
<td>Remarks</td>
</tr>
<tr>
<td>--------</td>
<td>---------</td>
</tr>
<tr>
<td>40</td>
<td>Scrutinise the shift reports (ME5) and record the details notified by the mine engineer and enter the result of any electrical tests on sheet (ME8) and mechanical tests on the appropriate plant history cards (ME3) or on special sheets. The date of events records will be the date of the relevant shift report.</td>
</tr>
<tr>
<td>41</td>
<td>Prepare defect action sheets (ME6) as instructed by the mine engineer. Record the relevant numbers of defect action sheets against events on the shift report. These should be prepared in duplicate. Top copy to be given to the mine engineer for issue to a craftsman. The second copy should be retained in the office.</td>
</tr>
<tr>
<td>42</td>
<td>Extract completed defect action sheets (ME6) and record any information marked by the mine engineer. Destroy the second copy of each completed defect action sheet and file the top copy with the craftsman’s daily shift report (ME5) on which the defect had originally been noted. The defect action sheet has the relevant daily shift report reference recorded on it for ease of matching and filing.</td>
</tr>
<tr>
<td>43</td>
<td>At the end of the week, scrutinise completed work instruction and report forms (ME4) to see that all daily and weekly tasks have been carried out. If any weekly task has not yet been completed, ring in red the corresponding task on the work instruction and report form for the following week. A ringed weekly task returned completed indicates that it has been missed for two consecutive weeks and should be reported to the mine manager.</td>
</tr>
<tr>
<td>44</td>
<td>At the end of the week examine remaining second copies of defect action sheets (ME6) and notify the mine engineer of outstanding top copies.</td>
</tr>
<tr>
<td>45</td>
<td>At the end of the week file all completed work instructions and report forms, shift reports, defect action sheets and applications for temporary amendments according to instructions issued by the mine engineer.</td>
</tr>
</tbody>
</table>

**REPORTING TO MINE ENGINEER**

Each week, after completing the check of previous week’s inspections, the main maintenance clerk should

<table>
<thead>
<tr>
<th>Action</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>46</td>
<td>Under the direction of the mine engineer or his nominee, prepare ME7 listing tasks entering their final week of tolerance. These should be listed on the appropriate side of ME7.</td>
</tr>
</tbody>
</table>
| 47 | Pass the completed ME7 to the mine engineer. The mine engineer should

<table>
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<th>Action</th>
<th>Remarks</th>
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<td>48</td>
<td>Scrutinise the list of tasks and decide whether any of them will not be completed during the final week. These should be transferred by him on to the other side of the form.</td>
</tr>
<tr>
<td>49</td>
<td>Sign the completed form and pass it to the mine manager.</td>
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### MAINTENANCE SCHEDULE

**AMENDMENT SHEET No.**

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<th>Reason for Amendment</th>
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**MANAGER'S BUREAU**

- Name: [Name]
- Title: [Title]

**PLANT SPECIFICATION**

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**ADDITIONAL DATA**

- Revision: [Revision]
- Date: [Date]

**SHARING LIST**

- Plant No.: [Plant No.]
- Number: [Number]

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This is a web-friendly version of Safe manriding in mines: First Report of the National Committee for Safety of Manriding in shafts and Unwalkable Outlets, originally produced by HM Inspectorate of Mines.
This is a web-friendly version of Safe manriding in mines: First Report of the National Committee for Safety of Manriding in shafts and Unwalkable Outlets, originally produced by HM Inspectorate of Mines.
This is a web-friendly version of Safe manriding in mines: First Report of the National Committee for Safety of Manriding in shafts and Unwalkable Outlets, originally produced by HM Inspectorate of Mines.
### Managers' Scheme for the Mine

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<td>Service</td>
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</tr>
</tbody>
</table>

#### Safety Measures
- Wear safety helmets.
- Use protective clothing.
- Regular health checks.

#### Records
- Monthly safety reports.
- Incident logs.

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31 Existing practice for routine non-destructive testing of winding engine components other than brake gear

Introduction

1 In Part 1A, paragraphs 112 and 118.1, reference is made to existing practices for routine non-destructive testing of winding engine components. The NCB has been aware for many years of the value of carrying out non-destructive testing of items of equipment where safety is of paramount importance. Details of the techniques to be employed and of the frequency of examination, when non-destructive testing of colliery gear is undertaken, are brought together in Notes of Guidance, Routine Non-Destructive Testing of Colliery Gear issued by the NCB Mining Department under Chief Engineers’ Circular CEC(74)3 dated 25 Jan 1974. The proposals set out in this section are based on this document and are suitable for application. However, they will be considered in future work and so may be modified if necessary. Winding engine components included are:

(1) Steam winding engines: drum shafts, crank pins and crosshead pins.

(2) Electric winding engines: drum shafts, intermediate shafts and reduction gears.

Frequency of examination

The following frequencies of examination are recommended:

(1) steam winding engines

(a) drum shafts once every two years

(b) crank pins once every two years

(c) crosshead pins once every four years

(2) electric winding engines

(a) drum shafts once every four years

(b) intermediate shafts once every four years

(c) reduction gears once every year

3 The frequencies stated are based on equipment in regular use. Where usage is particularly severe or the equipment is only operated occasionally, then the stated frequency should be varied to suit the circumstances, but may be amended to take account of mine holidays which can vary from year to year. It may be convenient to carry out non-destructive examination at times when equipment has been partially dismantled for another purpose.

Precautions to be taken during ultrasonic examination and magnetic particle inspection

4 (1) The responsible mine engineer should be informed, and his permission obtained, before any work on site is undertaken. Before carrying out any examination, the person in charge of the winding equipment eg banksman, winding engineman, must be informed so that the person carrying out the examination can do so safely. Suitable warning notices should be displayed.
(2) It is the responsibility of the mine staff to remove guards, covers etc and prepare the equipment for examination.

(3) If during examination it is necessary to rotate a shaft, the work should be done by the colliery staff who should take such precautions as are necessary to prevent the inadvertent movement of any bearing bottom section.

(4) Where portable mains operated electrical testing equipment is being used, it should be suitable for operation from a 110 volt supply to comply with the Coal and Other Mines (Electricity), (Second Amendment) Regulations 1974.

Method of reporting

5 (1) The responsible mine engineer should be notified verbally of the condition of the equipment examined as soon as practicable, and in any case before the person responsible for the examination leaves the site.

(2) A written report should be submitted within fourteen days of completion of the examination, and distributed to the engineers responsible for the equipment. This report should be such that the position, type and extent of any imperfection found are indicated on a sketch of the component concerned so that it can be identified readily on the component. Any extension of an imperfection should be detailed specifically in the report by comparison with previous reports.

(3) In cases where an examination was carried out from one end only of a component, this should be stated on the report, and the end from which the examination was made identified.

Procedure for shafts and pins

6 This procedure describes routine examination, in situ, of shafts and pins, including winding engine drum shafts, intermediate shafts, winding engine crank pins and crosshead pins, by ultrasonic means supplemented by magnetic particle inspection.

Areas to be examined

7 (1) Shafts and pins throughout their length by ultrasonic examination.

(2) Fillet radii of bearing journals and other changes of section, where practicable, by magnetic particle inspection.

The procedures to be adopted for each stage are:

Ultrasonic examination

8 (1) Where it has not been possible to examine a component prior to installation, or where no previous records are available, then a drawing should be obtained. Failing this, as detailed a drawing as possible should be prepared of the component to facilitate interpretation of the echo pattern.

(2) Any dirt, loose paint, scale or rust should be removed from the end faces of components.
(3) Selection of probe frequency will depend upon the material characteristics of the shaft or pin, but the frequency should be as high as possible, consistent with adequate penetration, without undue attenuation. In practice it will generally be found that probes within the frequency range 1 to 2.5 MHz are suitable.

(4) Longitudinal or compression wave probes with a zero angle of incidence of the entrant energy beam will generally be found adequate, but probes of shallow angle may be useful occasionally for examination of certain areas, depending on the component geometry.

(5) Separate or combined transmitter and receiver probes are equally suitable.

(6) Acoustic coupling media should be confined to oil or grease to prevent possible contamination of bearings.

(7) The whole face of both ends of shafts or pins should be scanned wherever possible. This may necessitate the use of special probes because of the close proximity of adjacent shafts etc, and may require the mine staff to remove fittings to expose the ends.

(8) In the case of a long shaft, in addition to searching the full length, parts of the trace should be expanded so that critical areas (section changes, parts in the region of drum cheeks, keyways etc) can be searched in greater detail.

(9) The echo pattern obtained for any shaft should be correlated with the echoes expected because of its geometry. This should be done during the actual examination and an instrument with a suitably calibrated delay will enable greater accuracy to be achieved.

(10) A record of the echo patterns obtained should be made, together with details of the testing technique, including sensitivity of the instrument, so that these can be referred to during subsequent examinations, and any deviations noted.

Magnetic particle inspection

9 Magnetic particle inspection is to be regarded as a supplement to ultrasonic examination, and not an alternative. The procedure to be adopted is as follows:

The surfaces to be examined should be cleaned so as to be free from oil.

(1) As a visual aid, surfaces should be painted with a quick drying white paint. There may be restrictions on the use of white paint affecting certain journal fillet radii, and if so, this must be specified in the order. Where no such restriction is specified, white paint shall be used.

(2) The quality of paint preferred is white magnetic crack detection paint. This paint should be diluted with industrial methylated spirit to the required consistency (generally within the range of between 1 to 2 parts spirit to one part paint), and be applied by brushing or spraying. After completion of the examination the paint should be removed from the bearing journals using a cloth dampened with industrial methylated spirit.

(3) The magnetic flux should preferably be produced by current flow, but a permanent magnet or electromagnet may be used. When the current flow
method is used, the probes should not be placed on the bearing journals or other working surfaces. Care should, however, be taken to ensure that the probes are close enough to the shoulders to ensure adequate magnetisation of the journal radii. The magnetic field strength for either method should be in accordance with the requirements of BS 4124: Part 2: 1968.

(4) Paraffin based, black magnetic flaw detection ink, complying with BS 4069: 1966 should be applied, preferably by spraying, whilst magnetisation is continuing. Care should be taken to reduce contamination of bearing oil by magnetic ink to a minimum. In cases of doubt, bearing oil should be changed.

**Procedure for winding engine gears**

10 Routine examination in situ by magnetic particle inspection, unless otherwise previously requested, should be confined to the teeth and other areas shown on fig 31.1. Attention should also be given to any areas where imperfections have previously been found and the remainder of the gears should be given a thorough visual examination. Where routine examination reveals the presence of imperfections in certain critical areas, more frequent examinations will be necessary.

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**Figure 31.1 Areas to be examined during routine non-destructive testing of gear wheels**

**Preparation**

11 (1) A routine examination could, with advantage, be made coincident with a complete oil change when the gearbox would be drained. If this is not possible the oil level in the gearcase could be lowered clear of the gear teeth to reduce the amount of oil on the surfaces which have to be examined.

(2) The surfaces to be examined should be cleaned free of oil or grease, using paraffin, and then painted by brushing or spraying with a quick drying white paint as a visual aid. The quality of paint preferred is white magnetic crack detection paint, spirit based, and is the same type as that recommended.
for examination of cage suspension gear. The paint should be diluted to a suitable consistency using approximately equal parts of paint and isopropyl alcohol (isopropanol) or industrial methylated spirit. If methylated spirit is used, this should be not less than 64 OP (over proof) in order to ensure satisfactory mixing and avoid the possibility of partial separation which could arise when using a low OP spirit due to its higher water content.

**Procedure**

1. The current flow method using alternating current should be used, but this may be supplemented by half wave direct current should the need arise.

2. Magnetisation should be carried out in two directions, at 90° to each other, wherever possible. The recommended current is 100 amp per inch (25.4 mm) of distance between probes, applied for approximately 5 sec, the number of applications being sufficient to ensure adequate magnetisation.

3. On no account should probes be placed on the flanks or corner edges of teeth and it is suggested that contact be made at the ends of the teeth unless the distance between probes is too great; contact can then be made at the tops and ends of the teeth.

4. To avoid arcing and excessive sparking current should not be switched on until the probes are firmly in contact with the component being examined. Conversely the probes should not be removed until the current has been switched off.

5. Paraffin based black magnetic flaw detector ink, complying with BS 4069: 1966 should be applied, preferably by spraying whilst magnetisation is continuing.

6. Where portable mains operated electrical testing equipment is being used the equipment should be suitable for operating from a 110 volt supply to comply with the Coal and Other Mines (Electricity) (Second Amendment) Regulations 1974.

7. Every care should be taken to prevent articles falling into the gearcase. If this does occur a colliery official must be informed.

8. After completing non-destructive examination paint may be removed from the teeth using a cloth dampened with either industrial methylated spirit or isopropanol.

**32 Model code for the testing of drum winding engines**

1. In Part 1A, paragraphs 122 and 126.2, reference is made to the model code for the testing of drum winding engines. In order to meet the provisions of the Coal and Other Mines (Shafts, Outlets and Roads) Regulations 1960, it is necessary to carry out a series of tests, when a winding engine which is ordinarily to be used for winding persons is first installed and thereafter at regular intervals to check that the safety system is properly adjusted.

2. The model code set out in this section details the quarterly testing procedures to be followed on drum winding engines serving vertical shafts. Explanatory notes in appendix 32.1 should be taken into consideration where appropriate when making tests.
3 Where other regulations apply or where there are individual equipments which create specific circumstances for which this testing code is not applicable then an appropriate test procedure should be laid down by the senior engineer or official concerned.

4 Where mechanically operated winding apparatus is ordinarily used for carrying persons through a shaft and the speed of winding can exceed 12 ft/sec (3.7 m/sec), Regulation 11(1) of the Coal and Other Mines (Shafts, Outlets and Roads) Regulations 1960; requires that there shall be provided an effective automatic contrivance to prevent overwinding so constructed as:

1) To prevent the descending cage or carriage from being landed at the lowest entrance to, or the bottom of, the shaft at a speed exceeding 5 ft/sec (1.6 m/sec).

2) To control the movement of the ascending cage or carriage to prevent danger to any persons therein.

5 Regulation 19(4)(b) requires that the operation of the automatic contrivance be tested at intervals not exceeding three months by attempting to land each cage when descending at an excessive speed.

6 In order to meet the provision of Regulation 11(1) the overwind safety system of a winding engine is designed to operate automatically in circumstances of maloperation of the controls by the winding engineman, or in the event of failure of the winding engine controls to function due to any cause. The testing procedure in this code includes the necessary tests to ensure that the safety system is properly adjusted to deal with these eventualities and to meet the requirements of Regulation 19(4)(b). The sequence of testing checks the satisfactory operation of the various components of safety apparatus before tests are carried out in which an attempt is made to land each cage at an excessive speed.

7 When a winding engine or safety equipment is installed comprehensive tests should be carried out and the results compiled in the form of a master record for subsequently checking compliance with the statutory landing speed and operation of the safety equipment. If some feature is altered such as a trip curve, retardation or winding cycle, or if doubt exists as to the authenticity of the master record, the further comprehensive tests should be carried out to establish a new master record. Subsequent periodic statutory test results should then be compared with the master record and with any previous test results. A copy of the master record for each winding engine should be kept in the winding engine house and the winder testing engineer should ensure that an up-to-date copy is available when he is carrying out statutory landing speed tests.

8 There are many types of winding engine and safety equipment in operation and the engineer responsible for testing should be fully conversant with the principles of the control and safety of those winding engines with which he is concerned. The explanatory notes in the appendices to this section should be carefully considered in relation to each individual equipment to ensure that the testing procedure is properly applied and that excessive testing is avoided.

9 It is important to appreciate that whilst winding equipment is designed to withstand the stresses involved during emergency trip conditions it is both unnecessary and undesirable during testing to initiate emergency trips beyond those required to prove the safe operation of the winding engine.
Testing procedure

10 Where reference is made in the code to testing a winding engine with an equivalent manload in one conveyance, it should be understood that it is necessary for the tests to be repeated with the load changed over to the other conveyance. The test load should be declared and equivalent to the maximum number of men specified as the man riding load per conveyance, at 1.5 cwt (75 kg) per man.

11 For a conveyance and counterweight system, the manload should be used when testing with reference to the conveyance, but the conveyance should be empty when testing with reference to the counterweight.

12 In the case of a single conveyance system, the declared test load should be used when proving the trip curve in a descending direction, but no load should be used when proving the trip curve in an ascending direction.

13 The banksman will normally be at his station during testing to supervise the loading and unloading of the conveyances. It is important that during any movement of the winding engine involving conveyances coming to the shaft top landing, he should be made aware of the intention and be ready to signal appropriately. This is particularly important when an artificial landing is being set up and removed.

14 In certain installations, particularly where there are balance ropes, it is considered advisable to station a person at the shaft bottom to detect any unusual circumstances which may arise, e.g., the balance rope fouling or the test load becoming displaced.

NB The requirements in paragraphs 13 and 14 above should be determined for individual shafts in the light of experience and knowledge of the installations.

15 It is important during a winding engine test that the following points be borne in mind:

(1) The engineer responsible for testing the winding engine, hereafter referred to as the winder testing engineer, shall be responsible for control during actual testing. Only persons essential to the performance of the test should be present in the winding engine house.

(2) The colliery mechanical and electrical engineers or their nominees should be present and be responsible for control of the winding engine during loading and unloading of the conveyance(s), and when any adjustments are being made. A nominee should be a person having supervisory duties; and adequate colliery staff should be present to make any necessary adjustments.

(3) The winder testing engineer should be able to give clear instructions to the winding engineman and have a clear view of the graph on the recording instrument at the same time.

(4) Notwithstanding that a winding engineman will be operating to the instructions of the winder testing engineer during testing, he should be advised before testing commences to stop the winding engine if he becomes aware of anything that will affect the safety of personnel or equipment.

(5) When adjustments are made, a check should follow to ensure that they are correct, by some safe method such as a trip at low speed with an ascending load, before attempting to resume the testing sequence.
General inspection

16 Before commencing the test, the winder testing engineer should ensure that the general condition of the winding equipment is satisfactory for the tests to be carried out, and that:

(1) Pivots, levers etc on the automatic contrivance appear to be free and functioning properly.

(2) Brake linings are not unduly worn and brake paths, together with adjacent equipment, are free from grease and oil.

(3) Brake posts and shoes are properly adjusted to give correct clearance and motion, linings are correctly bedded, and the brake engine or cylinders are within the limits of their travel. Where overtravel and wear switches are fitted these should be checked and operated manually.

(4) When the automatic contrivance is set for men winding, the winding engineman's and banksman's automatic indicators are functioning correctly.

(5) In the case of clutched drum winding engines, any interlocking gear between the clutch and loose drum brake is correctly adjusted (see paragraphs 21 to 24, of this section, and paragraphs 13 and 14 of appendix 32.1).

(6) In the case of steam, compressed air or hydraulically operated winding engines, the maximum working pressure is available.

(7) In the case of AC winding engines, the supply voltage is noted.

NB This general inspection should in no way replace normal maintenance inspection.

Operation of the mechanical brake and safety circuit

(See also paragraphs 2 to 21 of appendix 32.1)

17 This series of tests is to ensure that the level of braking torque is adequate and the safety circuit is functioning properly before tests at speed are made.

18 Brake holding tests – service braking see also paragraph 6 of appendix 32.1.

TEST 1A: TWO CONVEYANCES. Set the conveyances or conveyance and counterweight in balance and with the service brake fully on apply power torque to the winding engine drum, first in one direction and then the other until the maximum torque (as defined in paragraphs 37 to 41 of appendix 32.1) is applied, or until the drum moves through the brake.

TEST 1B: SINGLE CONVEYANCE. In the case of winding engines with only one conveyance which is unbalanced, the conveyance should first be loaded with the declared test load. With the loaded conveyance set in midshaft and the service brake fully on apply power torque to the drum in the downward direction until maximum torque (as defined in paragraphs 37 to 41 of appendix 32.1) is applied or until the drum moves through the brake.

19 Under the above conditions the mechanical brake should hold the drum stationary (see paragraphs 6, 13, 14 and 37 to 41 of appendix 32.1).
20. **Brake holding tests – clutched drum brakes** (see also paragraphs 13 and 14 of appendix 32.1). In all cases the brakes should first be tested with the clutch engaged in accordance with Test 1A (see paragraph 18 above). The procedure is then as follows:

**TEST 1C(a): LOOSE DRUM BRAKE.** Balance the conveyances and fully apply the loose drum brake. Take the fixed drum brake off with the clutch still fully engaged. Apply power in the downward direction of the loose drum conveyor. The brake should hold power torque at least equal to that required to raise an unclutched empty conveyor from the shaft bottom.

**TEST 1C(b): ALTERNATIVE TEST FOR LOOSE DRUM BRAKE.** An alternative method is to test the brake by setting the loose drum conveyor containing a load as specified below, just above the keps or, preferably, girders fixed across the shaft top. Apply the loose drum brake and disengage the clutch. The brake should hold the conveyor and load, showing that there is at least a 33% margin of brake holding torque for an empty conveyor. Should the braking be insufficient there will be slight movement of the conveyor onto the keps or girders. The amount of load depends on the position of the conveyances when declutching takes place in service. Where the normal practice of declutching with the loose drum conveyor at the surface is used, the load should be at least one third of the weight of the conveyor. If, for some reason it is necessary to declutch in service with the loose drum conveyor away from the surface, the load used for the test at surface should be at least one third of the weight of the conveyor plus one and one third of the weight of rope from the surface to the position where the loose drum conveyor is declutched in normal service.

**TEST 1D: FIXED DRUM BRAKE.** With the empty loose drum conveyor held at the surface by the loose drum brake and supported by keps or girders, disengage the clutch and wind the empty fixed drum conveyor to a position just above the shaft bottom. With the fixed drum brake off observe the current or steam pressure required to just lift the fixed drum conveyor. With the fixed drum brake fully on gradually apply power to drive the fixed drum conveyor downwards, up to at least the value of current or steam pressure required to lift the conveyor, or until the drum moves through the brake. The brake should be capable of holding the empty cage and suspended rope with at least a 50% margin on torque.

21. **Application tests – emergency braking.** Position the conveyance(s) or conveyance and counterweight in the shaft so that when the mechanical brake is released there is little or no movement of the drum. Where fast/slow brake gear is incorporated, set this gear in the fast braking position (paragraphs 15 and 16 of appendix 32.1 refer).

**TEST 2.** Take the brake fully off and, without applying power, trip the safety system by operating the winding engineman’s emergency stop device (see paragraph 17 of appendix 32.1). The brake should be applied automatically and the braking force at the brake engine determined and compared with the master record (see paragraph 18 of appendix 32.1).

**TEST 3.** Where back up operating gear is provided which applies the brake when there is a failure of the main brake steam, air or oil pressure, a test should be made to check that the back up protection is functioning correctly under failure conditions (see paragraphs 7, 8 and 9 of appendix 32.1).

**TEST 4.** With the brake fully on apply power to the winding engine and trip the safety system by operating the winding engineman’s emergency stop device (see paragraph 17 of appendix 32.1). In the case of electric winding engines, power to
the motor should immediately be interrupted or reduced; where two safety circuits are used, ensure that both are in working order; where two safety contactors are used in the same circuit, ensure that they both operate satisfactorily. In the case of steam or compressed air winding engines, the throttle should close automatically from the fully open position and where cylinder release valves are fitted, these should immediately operate to exhaust the cylinders.

TEST 5. Trip the safety circuit by hand from each safety device in turn (see paragraphs 19 and 20 of appendix 32.1). The back out circuit should be tested to ensure that when the brake lever is moved from the on position, power cannot be applied to aggravate an overwind. Each direction of overwind should be checked. The interval of time from operation of the overspeed trip mechanism to emergency brake fully on should be recorded. This can be done during or following application of the emergency brake. If different braking levels exist, this should be repeated for each level. (See paragraph 18 of appendix 32.1).

Three trip times should be measured and compared with the results of the master record. The average of these should be entered on the test certificate.

22 Where it is not possible to trip the overspeed mechanism, eg a Worrall Controller, the safety circuit should be tripped from another point. Where fast/slow braking is incorporated, make a record of the time interval with the fast/slow brake gear set in the slow position. The overall time lag, from trip to brake on, comprises several electrical and mechanical delays which should be recorded in the master record (see paragraph 21 of appendix 32.1). It is not necessary to check these individual times at each quarterly test.

23 When an electrical device is placed across overspeed contacts of an automatic contrivance in order to indicate the instant of trip, precautions should be taken to ensure that there is no risk of interference with the operation of the safety contactors. When any testing is undertaken on the winding engine, precautions should be taken to ensure that effective operation of the protective equipment for the winding engine is not impaired. Such precautions can be taken by operating the overspeed contacts manually to break the safety circuit with the winding engine stationary and the service brake applied. An approved method of obtaining overspeed trip indication is described in appendix 32.4.

Operation of the automatic contrivance and determination of retardation rates

24 This series of tests is to determine the characteristic trip-curve of the automatic contrivance, retardation produced by the brake and maximum landing speeds. Where two automatic contrivances are fitted as on some clutched drum winding engines, special consideration will be necessary to ensure that both contrivances are satisfactorily tested. Clutched drum winding engines should preferably be tested with long ropes.

Acceleration, trip characteristics and retardation tests

25 Place the declared test load in one conveyance (see paragraphs 10, 11 and 12 above) and set up an artificial landing for this conveyance as described in Appendix 32.2. An artificial landing will be maintained for one or other of the conveyances for Tests 6, 7 and 8, in this series. Any cam gear designed to reduce automatically the winding engine speed should be left set to the normal landing when the automatic contrivance and fast/slow brake gear are set to the artificial landing. However any speed controlling cam gear on older type Ward Leonard open-loop winding engines which is essential for overspeed protection should also be set to the artificial landing (see paragraphs 21 and 22 of appendix 32.2). Ensure
that for these tests the automatic contrivance is set for man winding. During Tests 6, 7 and 8, the following records should be taken:

- Trip speed.
- Distance of trip point from artificial landing.
- Retardation (see paragraph 36 of appendix 32.2).
- Distance of loaded conveyance from artificial landing when stopped.
- Maximum landing speed.

TEST 6. This first dynamic test should be at a slow speed with little or no power applied and could be achieved as follows. Raise the loaded conveyance a sufficient distance above the artificial landing, then lower it at a steady speed or allow it to gravitate until an overspeed trip occurs at about 5 ft/sec (1.6 m/sec).

TEST 7. Raise the loaded conveyance about 3 ft (about 1 m) above the artificial landing, and with the brake fully on apply maximum power torque to the winding drum in the direction of the artificial landing. Release the brake quickly. If maximum speed occurs at or just above the artificial landing, record this speed as the maximum landing speed. If not, repeat the test from different starting points until the maximum landing speed is achieved. Repeat this test, increasing the distance from the artificial landing by appropriate increments thereafter up to one drum revolution (see paragraph 26 of appendix 32.1) to obtain additional point on the trip curve. In the case of steam winding engines the torque applied will vary with crank position; include a test from the nearest point to the artificial landing at which the position of the cranks enables maximum torque to be developed for all drum winding engines. A test from the artificial landing in the wrong direction should be carried out, but care should be taken that the automatic contrivance is not damaged by overtravel. The amount of overtravel can be estimated by examining the distance moved after the trip which produced maximum speed at the artificial landing. The response of different winding engines varies and it will have to be determined by experience whether acceleration is greater when the brake is taken off before power is applied, or when power is allowed to build up before the brake is released; certain steam engines with steam restriction gear require rolling start tests (see paragraphs 25 and 37 to 41 of appendix 32.1).

TEST 8. Raise the loaded conveyance a sufficient distance above the artificial landing, say 1.5 to 2 drum revolutions, then lower it until an overspeed trip occurs at a speed greater than that recorded from one drum revolution in test 7. Repeat this test for about three increasing trip speeds up to and including maximum man winding speed to obtain additional points on the trip curve. Finally accelerate the winding engine from normal maximum man winding speed to obtain a trip at the maximum speed permitted by the automatic contrivance prior to the retardation portion of the trip curve. By considering the distance of this trip point from the start of the retardation portion of the trip curve, an assessment can be made of the minimum stopping clearance from the landing with this trip speed (see paragraphs 27 to 30 of appendix 32.1). Temperature of brake paths should be checked during the series of tests and cooling time allowed as appropriate.

When the above tests have been satisfactorily completed, the artificial landing should be removed (see appendix 32.2).

TEST 9. Raise the loaded conveyance from the shaft bottom as in a normal wind, and trip the safety system when a speed has been reached which will enable a
measurement of retardation to be easily recorded. For comparative purposes this
trip speed should be approximately the same for each quarterly test and it is
usually unnecessary to exceed a speed of 20 ft/sec (6.1 m/sec) (see paragraphs 32
to 35 of appendix 32.1).

26 Overwind setting

In order to check that the setting of the automatic contrivance has been correctly
restored, and to record the position of the overwind trip settings above the normal
landing, the following test should be made:

TEST 10. Instruct the winding engineman to raise slowly each empty conveyance in
turn, until an overwind trip occurs. Record the position of the conveyance above
the normal landing (see paragraph 43 of appendix 32.1). Any back up overwind trip
gear, such as headframe ultimate limit switches, should also be tested.

General check on equipment

27 After completing the tests, winding equipment, including ropes and suspension
gear, should be examined by a responsible engineer before normal winding is
resumed.

Statutory report

28 The winder testing engineer should make available to the appropriate mine
staff, test results and any other relevant information necessary to enable a report to
be made of the quarterly test on the statutory form.

Test certificate

29 The winder testing engineer should record the quarterly test results on a test
certificate (see example in appendix 32.3). The certificate should be attached to a
copy of the automatic contrivance trip curve and typical graphs of quarterly tests
are in appendix 32.3. Where the cage landing speed recorder used is of a type
which produces traces on a velocity/time base, then these traces should be
re-plotted on a velocity/distance base to arrive at the automatic contrivance trip
curve. The test certificate should then be signed by the winder testing engineer,
formally countersigned and distributed appropriately.

APPENDIX 32.1 Explanatory notes

1 The following explanatory notes should be read in conjunction with the relative
paragraphs of the Testing Procedure.

Operation of the mechanical brake and safety circuit
(See paragraphs 17 to 23 of code)

2 The series of tests, listed under this heading, is designed to check brake
holding capacity and satisfactory operation of the means of applying the brake
under emergency conditions. There are a variety of braking arrangements in use
but the following terms used in the text are applicable to all types:

SERVICE BRAKING is that controlled directly by the winding engineman from a
treadle or hand lever; both the rate of build up of torque and the level of torque, are
normally determined by the winding engineman.
EMERGENCY BRAKING is that applied automatically by safety devices. Both the rate of build up of torque, and the level of torque are present and independent of the winding engineman’s actions.

3 With the majority of older equipments, a single brake engine provides both the service and emergency braking force, and maximum retardation is the same whether the brake is applied by emergency devices or directly by the winding engineman.

4 With the majority of modern pressure control brake engines, separate adjustment of the service and emergency braking force is possible, but on most drum winding engines the level of service and emergency braking force would normally be the same. Where, for some reason service braking force is greater than the emergency level it should not be so much greater that dangerously excessive retardations can be caused when the mechanical brake is applied by the winding engineman. Routine service brake retardation tests are unnecessary and in any case this test should not be attempted on open-loop Ward Leonard winding engines. On a modern pressure operated brake engine, service braking force can readily be determined and related to the level of emergency braking.

5 All braking systems should be such that a winding engineman can apply service braking irrespectively of operation of the emergency brake and preferably without compounding the two. All brake engines should be fitted with pressure gauges so that there is a means of indicating or checking braking force.

*Brake holding test*
(See paragraphs 18 and 19 of code and paragraphs 37 to 41 of this appendix)

6 Regulation 9(1) of the Coal and Other Mines (Shafts, Outlets and Roads) Regulations 1960, states the statutory requirements in respect of the holding power of the mechanical brake. Tests 1A and 1B are designed to check that the brake complies with these statutory requirements. In certain cases it may be that the braking torque necessary to comply with Regulation 9(1) results in unnecessarily high and undesirable rates of retardation when applied under emergency conditions. Should this occur, application for exemption from the requirement of Regulation 9(1) may be made.

*Pressure failure: back up brake*
(See paragraph 21, Test 3, of Code)

7 Where a brake engine is designed so that braking force is applied by steam, air or oil pressure, additional provision is made for application of the brake, should pressure fail. Arrangements vary with different designs of brake engine but all follow the principle of applying the brake by deadweights or springs after pressure failure.

8 The method of testing depends on the particular system but basically, the test should prove that back up gear operates and applies the mechanical brake should the pressure of the operating fluid reduce to such a value that the main brake engine is not effective.

9 This part of the emergency braking facility may not regularly be used and/or may not normally be seen to function in isolation. Hence, when initially devising a testing procedure which requires the primary braking system to be held off, additional precautions should be taken to prevent uncontrolled drum movement in case of malfunction of the back up brake.
Back up brake on higher speed shaft

10 A number of older electric winding engines are fitted with auxiliary brakes on high speed shafts so arranged that these brakes cannot simultaneously be applied with the main emergency brakes. Auxiliary brakes can be interlocked to prevent simultaneous application with emergency brakes or simultaneously tripped with emergency brakes but with their application delayed.

11 There are also high speed shaft brakes designed to retard the mass of motor and high speed pinion and which are tripped and applied simultaneously with the emergency brake.

12 A critical examination should be made of each installation and a suitable retardation test procedure established to demonstrate the adequacy of the brake and the effectiveness of interlocking.

Clutched drum brakes
(See paragraph 20 of code)

13 When changing levels on a clutched drum winding engine, the loose drum empty conveyance should be held at the surface with the loose drum brake applied while the fixed drum is turned to raise or lower its empty conveyance. It is therefore necessary to check the torque of the mechanical brake in both the clutched and unclutched condition.

14 Unless the automatic contrivance and the fixed drum brake have been commissioned and tested for winding a single conveyance, unclutched operation should be solely for the purpose of level changing and on no account should manriding be carried out in the unclutched condition.

Fast/slow brake gear
(See paragraph 21 and 22 of code)

15 Fast/slow brake gear is fitted to some older type brake engines for the purpose of reducing the rate at which the braking force is applied. When the gear is in the slow braking position, the braking force, and hence retardation, builds up more slowly and, under trip conditions, maximum retardation will occur for a short period only. Slow braking is usually operative over the full speed portion and fast braking over most of the retardation portions of a wind.

16 On certain pressure operated brake engines, the pressure setting under trip conditions is controlled to reduce braking force in mid shaft. This arrangement does not alter the rate at which the brake is applied but for the purpose of testing should be considered as fast/slow braking.

Application tests – emergency braking
(See paragraphs 21 and 22 of code)

17 Reference Tests 2 and 4 – where a winding engine is not fitted with an emergency stop device, the safety system should be tripped by some other convenient means such as an overwind switch on the automatic contrivance.

18 Wherever possible a measure of emergency braking force at the brake engine should be made and the method for each winding engine approved by the senior engineer or official. For example, where brakes are applied by fluid pressure, it would suffice for a check to be made of pressures at each fixed level of braking. Where brakes are spring applied and pressure released, it may be necessary to
take physical measurements in order to check any change in spring nest setting with the brakes in the on position. Residual pressure if any should also be noted when the emergency brake is applied.

19. Reference Test 5 – the safety devices to be tripped as required by Test 5 should be declared for each winding engine by the senior engineer or official. It is essential that the automatic contrivance overwind and overspeed switches are included and any other safety devices incorporated for overwind protection such as brake overtravel switches. Test 5 can be carried out in a similar manner to Test 4; but it is satisfactory to check that the safety circuit is tripped without applying power to the winding engine motor.

20. It may be convenient, and in some instances advisable, for other electrical safety devices operating the safety circuit(s) to be tested at this time. This should be decided by the electrical engineer concerned.

**Time delays**

21. When carrying out periodic check tests it is necessary to obtain the time delay from initiation of an overspeed trip to full application of the mechanical brake. Should a test indicate that this time lag has increased so as to affect safety, it will be of some assistance in locating the cause if the various component times making up the total time, are known. It is therefore recommended that, when a winding engine is commissioned, measurements are taken of those component operating times that can reasonably be measured.

**Operation of the automatic contrivance and determination of retardation rates**

22. Paragraphs 22 to 42 of this appendix relate to testing of safety devices under running conditions.

**Acceleration and trip characteristic tests**

(See paragraphs 24 and 25 of code)

23. The first dynamic test is a trip at about 5 ft/sec (1.6 m/sec) and is to check operation of the safety equipment at a safe speed before commencing acceleration tests.

24. The acceleration tests are designed to ensure that the equipment complies with the requirements of Regulation 19(4)(b) of the Coal and Other Mines (Shafts, Outlets and Roads) Regulations 1960. These tests of the safety equipment are the most onerous in determining the maximum landing speed.

25. As indicated in the text, to produce maximum acceleration power has to be built up before or after the brake is released; if the latter, then minimum power should be applied when the winding engine is moving. It is only necessary to carry out the test found to be the more onerous during commissioning tests.

26. Reference is made in the text to carrying out tests at appropriate distances within one drum revolution of the artificial landing. For guidance, it is suggested that increments of 3 to 6 ft (1 to 2 m) from the artificial landing up to one quarter of one drum revolution should be used and thereafter 0.5, 0.75 and 1.0 drum revolution. It should be appreciated that the positions indicated above are not rigid requirements and, in general, acceleration tests from positions within the last revolution of the drum are all that is required and the number of tests should be kept to a minimum. If a winding engine is fitted with acceleration relief on the overspeed mechanism of
the automatic contrivance, it is necessary to check that this feature does not allow an excessive speed towards the landing owing to lag in the mechanism after changing direction.

27 The trip characteristic of the automatic contrivance is the curve indicating winding speed at which the safety circuit trips at various positions of the conveyance relative to both ends of the wind.

28 During commissioning the full trip curve is established, but at a quarterly test it is sufficient to prove the curve in relation to speed and distance from the landing by using a minimum number of trips. Trip speeds and distances should be varied between quarterly tests so that the full characteristic is adequately verified during one year.

29 After the acceleration tests have been completed, the next test should be at a speed just sufficient for the rate of retardation to be accurately determined. This is to ensure that braking characteristics have not changed so that higher speed tests can be safely conducted. About three tests are then carried out, the last being at the maximum possible winding speed when the automatic contrivance is in the man winding position.

30 The method of achieving this maximum possible winding speed will need to be determined for each winding engine and approved by a senior engineer or official. On most electric winding engines it can be achieved by accelerating the loaded conveyance down the shaft until normal maximum speed is reached, and then by removing power from the motor allowing the out of balance load to accelerate the winding engine until an overspeed trip occurs at the maximum speed permitted by the automatic contrivance. Preferably, the trip should occur just before the retardation part of the trip curve is reached. Experience and knowledge of a particular installation will indicate the point in the wind at which this test should start and the position in the wind at which power should be removed from the motor in order to achieve such an overspeed trip. Consecutive test of this type should not be carried out in order to try to make the overspeed trip coincide with commencement of the retardation part of the wind, as this may cause over heating of brake paths. It is preferable to establish the ideal starting point during a series of quarterly statutory tests. If an overspeed trip is not obtained before the retardation part of the wind is reached because out of balance load does not produce sufficient accelerating torque, or there is not adequate accelerating distance due to shallow depth of shaft, then the overspeed trip which occurs at the commencement of the retardation period should be recorded as the maximum possible winding speed. Where there is closed-loop electrical control, it will be necessary to provide an overspeed test switch to enable this test to be carried out. On steam winding engines, the maximum possible winding speed can be determined by applying steam and accelerating the winding engine such that an overspeed trip is achieved just before the descending loaded conveyance reaches the retardation part of the wind.

31 Completion of this series of tests in the manner described should enable the trip curve to be adequately verified.

Brake retardations
(See paragraphs 24 and 25 of code)

32 The rate of retardation produced by emergency braking is measured during the trip curve characteristic tests. Rates of retardation will depend on characteristics of the particular winding engine. The only general guidance that can be given is that the rate of retardation should be the minimum commensurate with satisfactory
compliance with statutory regulations, together with adequate stopping clearances, taking into account normal variations in coefficient of friction between brake linings and paths.

33 In the case of parallel drum winding engines without balance ropes, minimum retardation under emergency braking conditions occurs when the descending load approaches the bottom of the shaft. Maximum retardation occurs in the same position but with the load ascending. In the case of parallel drum winding engines fitted with balance ropes equal in weight to the winding ropes, retardation is independent of conveyance position.

34 In the case of parallel drum winding engines with only one conveyance, the difference in rate of maximum and minimum retardation will be large unless a control is fitted which reduces braking force when the conveyance is ascending. Where such a control is provided, it should be in operation when ascending load trip tests are carried out.

35 With bi-cylindro and conical drums, maximum retardation will generally occur when an ascending loaded conveyance is approaching the surface with the ascending rope coiling on to the large diameter and the descending rope uncoiling from the small diameter. It is usually preferable to have the recording instrument calibrated relative to the small diameter. Retardations may be referred to the large diameter by calculation.

36 Measurement of the rate of retardation produced by emergency braking may be made on a velocity/distance or velocity/time base. However, it is essential that measurement is made at each quarterly test using the same method and parameters, so that the basis for comparisons with the master record do not vary. The rate of retardation recorded on the test certificate should be on the average from the point at which retardation commences to the point at which the winding engine drum comes to rest.

**Maximum power torque**

37 A number of tests require that maximum power torque be applied to the drum. This is not necessarily the maximum torque of which the winding engine is capable and note should be taken of the following paragraphs.

38 In the case of twin cylinder simple steam engines, maximum torque will normally occur with the engine cranks at 45° from inner dead centre and with inlet valves open to admit maximum steam pressure in the direction required for test. It is, however, preferable to check at each of the four crank positions at 45° to the line of stroke the significance of such features as servo action of the brakes, ovality of brake paths, and drum balance weights. A pressure gauge should be fitted to measure steam pressure between the throttle valve and engine. There is a variety of compounding arrangements in use and each compound steam engine should therefore be individually considered and the crank position for maximum torque ascertained.

39 Use of the maximum power torque of which an electric winding engine is capable may lead to equipment damage or application of excessive braking torque and it may be necessary to limit power torque applied by the winding engineman during brake tests unless an overriding torque limiting device is fitted.

40 In the case of AC and DC winding engines where no torque limiting device is fitted, the test should be carried out at a current corresponding to 1.1 times the maximum torque required in service for the normal duties, taking into account any
permissible variation in loading conditions. Where the motor(s) will not develop 1.1 times this maximum torque, or where a torque limiting device is fitted, the maximum torque that is available to the winding enginemen should be used for this test.

41 The definitions of maximum torque stated in the preceding paragraph have been reached in agreement with HM Mines Inspectorate, pending further investigation and consideration of this subject in relation to brake performance.

Combined electrical and mechanical braking in Ward Leonard winding machines

42 There are various arrangements for initiating retardation under trip conditions on Ward Leonard winding engines but, whatever the arrangements, some electrical effect will be present which may assist or oppose the mechanical brake. Wherever possible, the control should be set such that, following an emergency trip, minimum electrical braking occurs when the mechanical brake is fully applied and effective with the maximum load descending and the conveyance near the bottom landing. Where a balance rope equal in weight to the winding ropes is fitted, the position of the conveyance is not of consequence in this respect. It is recommended that retardation under normal tripping conditions be checked quarterly. At commissioning, tests should be carried out to ensure that the mechanical brake will protect the winding engine with zero electrical torque. At this time, the separate and combined effects of mechanical and residual electrical braking should be clearly identified and recorded as standards. At a quarterly test the combined effect can then be compared with the commissioning standard. The procedure for this test should be agreed by a senior engineer or official before any such tests are carried out and form part of the master record.

Overwind setting

43 The position of the overwind switch or trip device above bank will depend upon the distance that it is necessary to raise the conveyance above the landing during normal winding operations. The switch or trip device should be set to operate at the minimum overwind distance commensurate with normal manoeuvring requirements.

APPENDIX 32.2 Setting an artificial landing

1 Four methods of setting up an artificial landing are indicated below.

2 Where the automatic contrivance is fitted with moveable cam dials for each conveyance, Method 1, which avoids uncoupling the drive, should be used.

3 For other automatic contrivances, except Worsley Mesnes pneumatic controllers, Method 2 or 3 should be used but additional protection should be afforded for the loaded conveyance when ascending. For this purpose it is suggested that, during testing, a limit switch be introduced into the trip circuit and so arranged to operate when the loaded conveyance required is at a distance from the highest landing equal to the distance required for normal retardation from maximum speed. Wherever possible Method 3 should be avoided because of the danger of moving the winding engine without protection.

Method 1

4 Place the declared test load in one conveyance (see paragraphs 10, 11 and 12 of code).
5 Wind the loaded conveyance to the lowest level and stop it at the normal landing position. Suitably mark the sliding part of the automatic contrivance cam dial in relation to the non-sliding part. Note the clearance between the overwind cam and its roller at the shaft bottom position. Wind the conveyance two or three drum turns up the shaft; loosen the sliding part of the dial and move it bodily, complete with the cams, to its shaft bottom position. The dial should then be made secure and a temporary mark put on the depth indicator showing the position of the artificial landing. It is normal practice to mark the drum relative to a fixed point as a check and to facilitate resetting. The setting of the overwind switch should then be checked by slowly lowering the loaded conveyance until an overwind trip occurs.

6 The procedure of resetting to the normal landing is as follows. Wind the conveyance to the artificial landing. Loosen the sliding part of the dial and turn it until the marks on both the sliding and the non-sliding parts of the dial coincide. Secure the two parts together and instruct the winding engineman to wind slowly to the normal landing position where the settings can be rechecked. Remove the temporary mark on the depth indicator and test the overwind trips as described in Test 10 (see paragraph 26 of code).

**Method 2**

7 Place the declared test load in one conveyance (see paragraphs 10, 11 and 12 of code).

8 Wind the loaded conveyance to the lowest level and stop it at the normal landing position. Suitably mark the two halves of the drive coupling nearest to the automatic contrivance relative one to the other and with reference to a fixed point. Wind the conveyance two or three turns up the shaft noting the number of revolutions of the automatic contrivance coupling. Uncouple the drive and reset the automatic contrivance by hand, turning back the same number of revolutions to the fixed mark previously made, and reconnect the coupling. This position may now be regarded as the artificial landing and a temporary mark should be made on the depth indicator. The setting of the overwind switch should be checked by slowly lowering the loaded conveyance until an overwind trip occurs.

9 It is normal practice to mark the drum relative to a fixed point as a check and to facilitate resetting.

10 The procedure for resetting to the normal landing is as follows. Wind the conveyance to the artificial landing, uncouple the drive and reset the automatic contrivance by hand until the marks on the two half couplings coincide, making sure that the number of revolutions of the half-couplings is the same as that previously noted when setting the artificial landing. Reconnect the coupling and instruct the winding engineman to lower the conveyance slowly to the normal landing position where the settings can be rechecked. Remove the temporary marks on the depth indicator, drum and coupling, and test the overwind trips as described in Test 10 (see paragraph 26 of code).

**Method 3**

11 Place the declared test load in one conveyance (see paragraphs 10, 11 and 12 of code).

12 Wind the loaded conveyance to the lowest level and stop it at the normal landing position. Disconnect the drive to the automatic contrivance, suitably marking where the drive is split and marking the drum relative to a fixed point.
Wind the conveyance two or three turns up the shaft using the drum mark. Re-couple the automatic contrivance drive using the marks.

13 This position may be regarded as the artificial landing and a temporary mark made on the depth indicator. During movement of the winding engine with the drive uncoupled the winder testing engineer should be in a position to operate the emergency trip in case the winding engineman attempts to wind in the wrong direction. The setting of the overwind switch should be checked by slowly lowering the loaded conveyance until an overwind trip occurs.

14 The procedure for resetting to the normal landing is as follows. Wind the conveyance to the artificial landing and disconnect the drive to the automatic contrivance. Wind the conveyance slowly down to the normal landing. The automatic contrivance drive is then reconnected at the correct marks. During this movement of the winding engine, the winder testing engineer should be in a position to operate the emergency trip in case the drum moves in the wrong direction, moves too fast, or travels beyond the normal landing. Remove the temporary mark on the depth indicator drum and the coupling mark and test the overwind trips as described in Test 10 (paragraph 26 of code).

**Method 4** (for a Worsley Mesnes pneumatic controller)

15 Place the declared test load in one conveyance (see paragraphs 10, 11 and 12 of code).

16 In this controller, a pair of travelling nuts mounted on rotating screws provide a distance reference and, at the start of the retardation period, the top of a nut contacts two small rollers attached to a lever which raises the piston of the deceleration cylinder.

17 To provide an artificial landing, a split collar is placed on top of the appropriate travelling nut such that the collar contacts the two small rollers two or three drum turns in advance of the travelling nut depending on clearance required for the artificial landing. The collar should be provided with hinges and fastener and centrally located around the screw thread, but should not rotate. A recess should be provided in the base of the collar to accommodate the overwind adjustment thread, thereby ensuring that the collar contacts the top of the adjusting nut.

18 It is necessary to check that the steam restriction gear is in operation over an adequate distance before the artificial landing. This is not normally advanced to the artificial landing, but may require advancing in certain shallow shaft installations.

19 As in the other methods, the drum and indicator should be suitably marked during the use of the artificial landing.

20 After setting the artificial landing but before commencing the dynamic tests, check the overwind setting by slowly lowering the conveyance until an overwind trip occurs. When the artificial landing has been removed, test the overwind trips as described in Test 10 (see paragraph 26 of code).

**General**

21 When setting up an artificial landing, the position of the fast/slow brake cam gear will depend on the particular test. For Tests 2 to 5 (see paragraph 21 of code) the cam gear should be set in the fast position except where indicated. For Tests 6 to 8 the cam gear should be set to the artificial landing so that any slow braking in the normal retardation zone is taken into account.
22. The speed control cam gear used on older type open-loop Ward Leonard winding engines is usually an essential part of the overspeed protection system. Thus, although this cam gear is not in operation when carrying out the automatic contrivance characteristic tests, it is necessary for it to be set to the artificial landing for the acceleration tests.

**APPENDIX 32.3 Record of tests**

![Record of tests image]

This is a web-friendly version of Safe manriding in mines: First Report of the National Committee for Safety of Manriding in shafts and Unwalkable Outlets, originally produced by HM Inspectorate of Mines.
APPENDIX 32.4 Overspeed contacts: conditions to satisfy paragraph 23 of code

1 In order to carry out tests required by the model code, the precise instant of opening of the overspeed switch is required to be known, and also that it is this switch that has tripped the safety circuit and caused the mechanical brake to be applied.

2 The conditions relating to the use of this switch for this purpose are laid down in paragraph 23 of the model code. These conditions are necessary to maintain the integrity of the switch and associated circuitry. This circuit responds to malfunction of the winding engine speed control system whether manual or automatic. A method of complying with the requirements of paragraph 23 interposing is suggested below.

3 A high resistance interposing relay may be connected across the overspeed switch in the following manner. Two resistors of high integrity, each mounted on its own insulating board, attached to a metal plate and adequately protected by a metal cover, should be used for connecting into the leads for the overspeed switch to the relay, one resistor in each lead. The resistors should be of such a value that, when connected in series across the overspeed contacts, the current in the safety circuit is reduced to about 10% of the current required to hold in (not close) the safety circuit contactors.

4 For reasons of robustness and reliability, the resistors should be of a vitreous coated wire wound type, and at least 3 watts rating or 3 times that wattage required by the rating of the circuit whichever is greater.
5 Reliance should not be placed on the wire connections of a resistor as the sole means of its support. The body of a resistor itself should be held by a suitable clamp.

6 The purpose of mounting the resistors on separate insulating boards on a metal plate, which should be earthed, is to ensure that a fault will be an earth fault rather than a short circuit.

7 The leads from the overspeed contacts to the resistors should be as short as is practicable and should be screened, as are the cables in this section of the safety circuit, unless the leads are so short that high integrity is maintained by disposition and clamping. The leads to the interposing relay need not be screened as a short circuit at this point would not interfere with the operation of the safety circuit.

8 The interposing relay should be incorporated so that no live contacts exist on the socket outlet to be used for the connections required to the test equipment.

9 The above arrangement is one method of achieving the required integrity, others could be equally acceptable but should be at least to the same level of integrity.

33 Suggested specification for operational and formal training of winding enginemen

Introduction

1 In Part 1A, paragraph 127, reference is made to the training of winding enginemen, and to the need for formal training. It is also recommended in paragraph 130(1) that a training specification be established, and an example of such a specification is outlined below.

Statutory requirement for appointment

2 To operate mechanically or gravity operated winding apparatus at a mine shaft or staple pit when persons are being carried, the Mines and Quarries Act 1954 Section 42(i) requires the manager to appoint sufficient numbers of competent male persons of not less than 22 years of age.

Statutory duties

3 The statutory duties of persons operating winding apparatus in shafts and staple pits are detailed in Part IV of The Coal and Other Mines (Shafts, Outlets and Roads) Regulations 1960.

Operational (on the job) training

4 The Mines and Quarries Act 1954 Section 88 requires that trainees be given adequate instruction to ensure that they are competent to operate winding apparatus safely and efficiently without supervision. This instruction, forming the major part of the training should be given by a competent winding engineman duly authorised for the purpose.

5 Operational training should incorporate instruction in, and carrying out practically under supervision, the functions and duties of a winding engineman including:
(1) Operation of a winding engine during routine testing, including the overwind and landing speed tests required by Regulation 19(4) of The Coal and Other Mines (Shafts, Outlets and Roads) Regulations 1960.


6 Because of differing circumstances at each mine, shaft and installation, there can be no formalised programme for operational training, but operation by the trainee of a winding engine during testing and emergency winding should not take place until the supervising winding engineman is satisfied that the trainee is sufficiently proficient in normal operation of the winding engine. Operation of the winding engine by the trainee during routine testing and emergency winding practice should be additionally supervised by a member of the mine engineering staff or the winder testing engineer as appropriate.

**Formal training**

7 In addition to instruction and operating supervision by a competent winding engineman, formal training should be given by members of the mine engineering staff or other competent persons nominated for the purpose. This training should aim at reinforcing operational training and ensuring that various operating, safety and emergency procedures, and, where relevant, cleaning, oiling and external examination duties, are clearly understood.

8 As an aid to both operational and formal training, copies of the Operating Manual for the winding engine (see Part 1A, paragraph 128) should be issued to the trainee, the winding engineman and to all other persons nominated to give this training. Persons nominated to give formal training should examine all relevant instructions, codes and information documents so that any aspects of these which are appropriate to particular winding equipment can be incorporated in training. Close liaison should be maintained between the winding engineman supervising the operational training and those persons nominated to give formal training so that the two are sensibly integrated.

9 Formal training should include the following subjects.

**Instructions and information**

10 Ensure that the trainee is issued with a copy of instructions and any other information, relevant to his functions and duties, for his perusal and retention. Reasonable steps should be taken to assist the trainee’s understanding of these instructions and information which should include:


(2) Book 3 of the books prepared and designated for the purpose of Section 137.

(3) The Coal and Other Mines (Shafts, Outlets and Roads) Regulations 1960.


(6) The Operating Manual for the winding engine.
(7) Any working procedures, instructions, directives or other information applicable to the winding engine.

Communications and reports

11 The trainee should have been instructed during operational training in procedures applicable when reporting to work as a winding engineman at a mine. Additionally, the functions of management and specialists which affect the winding engineman should be outlined; and emphasis given to:

(1) The importance of regular communication between winding enginemen, which can best be achieved by written routine shift reports to enable oncoming winding enginemen to be made aware of events which have taken place during previous shifts.

(2) The need for regular discussions between the winding engineman on duty and mine engineering staff responsible for winding engine maintenance and the importance of reporting immediately any abnormal behaviour of the winding engine or auxiliary equipment.

(3) Ensuring that the trainee is aware of, and understands fully, his duties with regard to cleaning, oiling and examinations of the winding engine and auxiliary equipment. This could be accomplished by detailing the work in standing instructions and check lists and by reporting in the shift reports referred to in (a) above.

Normal winding procedures

12 Training should include the following:

(1) Imparting a basic understanding of the functions of the winding engine control equipment. This should not involve technicalities, but rather an appreciation of the functions of some of the principal control items and of factors which can affect control of the winding engine, eg the effect of excessive temperature in the liquid controller on winding engine control.

(2) The opportunity of visiting pit bank, pit bottom and intermediate insets, where the system and methods of operation at these stations and the main features or shaft furnishings can be explained.

(3) Emphasising the importance of concentration and correct interpretation of signals by winding enginemen, particularly in the case of multi-deck cage systems.

Infrequent winding procedures

13 There are a number of winding operations which occur infrequently and some (eg changing a conveyance) with which a trainee is unlikely to be directly involved before being appointed as a competent winding engineman. It is necessary to ensure that winding enginemen and trainees are aware of procedures used when carrying out infrequent operations and that they understand any particular manoeuvring and control requirements when winding heavy out-of-balance or awkward loads. Typical winding procedures are:

(1) Recapping a winding rope.

(2) Replacing a winding, balance or guide rope.

(3) Changing a conveyance.
Safety equipment and procedures

14 (1) Explain the purpose of the various safety devices and basic functions of the safety system, for example, protection against overload, overwind, overspeed, slack rope etc.

(2) Ensure that the trainee is aware of the different tripping and safety arrangements in so far as they affect his operation of the winding engine, eg trips arising from the abnormal conditions classified in the three categories listed in paragraph 46 of Part 1A, or brake engine overtravel, low air or oil pressure etc.

(3) Ensure that the trainee understands, and is capable of implementing, any emergency stop procedure and consequent action.

(4) Ensure that the trainee is aware of precautions to be taken, and procedures to be followed, such as in the event of:

(a) A total shutdown when the winding engine will not be used eg a holiday period.

(b) Resuming work and preparing for winding operations following a total shutdown.

(c) Severe weather conditions likely to affect winding operations.

(5) Explain the causes and consequences of slip on friction winding engines and ensure that the trainee is aware of action to be taken when slip occurs.

(6) Explain the need to vary the parking position of the conveyance(s) to minimise the effect of weather and mine ventilation on the winding ropes.

Emergency procedures

15 Ensure that the trainee is made aware of the winding engineman's role in any emergency procedure such as:


(2) Temporary use of auxiliary emergency equipment.

(3) Location of controls for emergency lighting after a lighting failure.

(4) Transportation of a seriously injured persons through a shaft.

(5) Action following fire or bomb alert in the engine house.

34 Principal duties of winder testing engineers and suggested syllabus for their training

1 In Part 1A, paragraph 133, the duties, selection, training and certification of winder testing engineers are discussed. This section lists the principal duties of winder testing engineers, together with proposals for their specialist training. It is recommended in paragraph 136(4) of Part 1A that these proposals for specialist training be used as a basis for a formal scheme of training.
**Principal duties of winder testing engineers**

2 The principal duties of winder testing engineers include those listed below:

(1) Supervise or carry out tests on new winding engines, and on existing winding engines following modifications affecting the operation of the safety system, to establish master records of the performance characteristics of automatic contrivances and associated safety and interlocking equipment.

(2) Organise and carry out tests in accordance with the requirements of the testing codes for winding engines in order to ensure satisfactory performance of automatic contrivances and associated safety and interlocking equipment.

(3) Compare test results with the master record and, when necessary, arrange with mine engineering staffs for adjustments to be made, and any other necessary action taken, to maintain satisfactory performance of automatic contrivances and associated safety and interlocking equipment.

(4) Prepare and submit reports giving the results of tests, including details of adjustments made, other action taken, and any observations or recommendations relating to the winding engine safety systems and equipment.

(5) Ensure that testing equipment in use is properly maintained and calibrated.

(6) Give special assistance as directed on matters concerning safe and efficient operation of winding engines and related equipment.

**Proposed specialist training for winder testing engineers**

3 The following details the scope and nature of specialist training considered necessary for future winder testing engineers. This specialist training is divided into operational and technical training. The proposals for technical training are presented under subject headings with an indication of the broad objectives and subject matter involved.

**Operational training**

4 Operational training should constitute instruction in and the carrying out under supervision of winding engine testing as required by the testing codes. Instruction should be given and supervision afforded, by a person competent in winding engine testing and nominated for the purpose, and include interpretation and application of testing codes in respect of each winding engine with which the trainee is to be concerned. Particular attention should be given to ensuring that trainees are made aware of precautions necessary for their own and other persons’ safety and for the safe testing of the particular winding engines.

**Technical training**

5 Technical training should constitute sufficient instruction in the basic design, control and operating principles of winding engines and their safety systems, and equipment, to ensure safe and efficient testing of those winding engines with which the trainee is to be concerned. The training should be given by persons nominated to give operational training or, where appropriate, by other nominated persons and should include the following elements.
6  **Winding arrangements.** Objective – to show how power and braking requirements vary with different systems and different winding cycles and to show how this affects design of the mechanical braking system.

(1) Duty cycle diagrams for basic winding arrangements – parallel drum with or without balance rope, bi-cylindro conical drum, single and multi-rope friction winding engines, single and multi-deck cages, skips.

(2) Electrical and mechanical braking requirements – torque variation and power dissipation.

7  **Winding engine drives.** Objective – to identify the cardinal control features of different types of drive with particular reference to control of electrical braking and emergency tripping.

(1) AC. Rotor control arrangements (liquid and metallic resistances), reverse current and dynamic braking, basic closed-loop control (torque and speed), emergency tripping.

(2) DC (MG set). Open loop Ward Leonard system, field control arrangements, cam gear arrangements, emergency trip, closed-loop control.

(3) DC (CONVERTOR). Basic principles control arrangements (cross-connected, armature and field reversal), emergency tripping.

(4) STEAM. Twin cylinder simple arrangements, throttle and reversing control, steam cut-off control, compound engine arrangements, common valve arrangements, emergency tripping.

8  **Mechanical braking arrangements.** Objective – to identify characteristics of different brake shoe and brake engine arrangements and to consider factors affecting design and operation of mechanical brakes with particular reference to emergency operation.

(1) BRAKE ARRANGEMENTS. Calliper, centre suspended etc, pressure distribution, resultant forces.

(2) BRAKE ENGINE ARRANGEMENTS. Deadweight, position control, force balance system, pressure control, fast/slow braking, differential brake, fail-safe requirements, back up brakes.

(3) SPECIFIC BRAKE ARRANGEMENTS. Details of different manufacturers’ equipment, service and emergency braking systems, control and trip valve arrangements.

(4) BRAKE LININGS. Materials, friction characteristics, pressure – velocity rating.

9  **Winding engine safety systems.** Objective to consider statutory and mandatory requirements related to safe operation of winding engines and prevention of overwinds, and to examine functioning of different automatic contrivances with different drives and different braking and tripping arrangements.

(1) STATUTORY AND MANDATORY PROVISIONS. Coal and Other Mines (Shafts, Outlets and Roads) Regulations 1960, special regulations for friction winding engines, relevant owner’s instructions.

(2) AUTOMATIC CONTRIVANCES. Principles and characteristics of different types.
(3) SAFETY SYSTEM ARRANGEMENTS. AC winding engines, DC winding engines, steam winding engines, drum and friction winding engines.

10 Winding engine testing. Objective – to relate testing codes to different safety system arrangements and to consider in some detail the various points and precautions included in testing codes.

(1) Safety precautions during testing.

(2) Consideration of special safety system arrangements.

(3) Testing instruments and interpretation of records.
Other winding practices

35 Suitability of AC winding engines with closed-loop control for automatic winding

1 In Part 1A, paragraph 143, reference is made to the inherent characteristics of AC winding engines which can produce unsatisfactory operational features in some circumstances of speed, loading and control system response.

History

2 In an endeavour to produce speed control on an AC winding engine and obtain a performance comparable with that of a DC winding engine operating on the Ward Leonard principle, dynamic braking and closed-loop control techniques were applied.

3 This degree of control was never achieved in practice owing to a number of factors, such as the inherent non-linear characteristics of the AC slipring motor when using a variable resistance for speed control. Stator reversing and dynamic braking contactors take time to operate, during which period there can be partial loss of control; the liquid controller takes time to respond to the speed control system and resistance of the electrolyte is sensitive to temperature so that response of the system can vary until a mean working temperature is reached. These factors contribute to instability and erratic behaviour. Grid resistors offer some advantages over liquid controllers; but in practice resistor steps are so coarse that hunting between two steps may occur, due to neither step satisfying the requirements of the control system, and so set up oscillations in the winding system.

4 The difficulties described give rise to wide variations from the designed cycle speed, and variations in rates of retardation make it impossible to achieve a constant approach speed and accurately land the conveyance at decking level of all load conditions. A possible solution would be to employ measuring techniques to change automatically the control circuits to compensate for differing loads, but this would not overcome the inherent problems of equipment response time which limit the loop gain of the closed-loop system to the order of 12 : 1.

5 Designers have accepted that the AC winding engine is only suitable for automatic operation where fixed loads are being wound, but in view of the large number of AC winding engines at work in the UK, and accepting that safer winding practices could be established by modifying these winding engines to automatic control, it was felt that the problems needed further investigation.

Tests

6 After discussion with manufacturers about various control schemes, it was decided to carry out tests on two installations employing a supervisory closed-loop control system but normally operated manually.

TEST 1

7 The first installation to be tested was a two rope ground mounted friction winding engine used for winding men and materials. Its technical particulars are:

GEC 1900 hp (1417 kW) 3.3 kV, 492 rev/min slipring induction motor equipped with rotor grid resistors, dynamic braking, and a closed-loop supervisory control system.
Full speed: 40 ft/sec (12.19 m/sec).

Shaft depth: 890 yd (814 m).

Payload: 81 men or 9 ton (9.15 tonne) dirt.

Conveyances: two triple deck cages each weighing 15 ton 9 cwt (15.70 tonne).

Duty cycle man winding: acceleration 10 sec; full speed 50 sec; retardation 26 sec.

8 With the GEC closed-loop supervisory control system, the driver starts a wind by putting the power level in to the full speed position and taking the brake off. The winding engine accelerates to full speed and under control of the supervisory system at the end of the full speed period, cams operate a rheostat to cause the engine to decelerate to creep speed. When decking level is reached, the winding engineman applies the brake and moves the power lever to the off position.

9 Tests were carried out to ascertain the behaviour of the winding engine under varying load conditions, using an ultra violet recorder to measure rotor current and a Lintott conveyance landing speed recorder (X – Y plotter). Six winds were carried out with a test load equivalent to 40 men in one conveyance, and two winds with empty conveyances.

Test 1 results

10 WIND (1). With the test load descending and the empty conveyance ascending, the winding engineman was instructed to put the power and brake levers into full power and brake off positions respectively, and to allow the winding engine to operate under the influence of the closed-loop control system. Acceleration was uniform at 6.6 ft/sec² (2.01 m/sec²) until full speed of 40 ft/sec (12.19 m/sec) was reached. At the end of the full speed period, power was automatically removed and dynamic braking automatically applied, but owing to inherent delay in applying dynamic braking the winding engine tripped on overspeed 2.5 sec after the change.

11 WIND (2). The winding engineman was given instructions as for wind (1) but with the test load ascending. Acceleration was uniform at 5 ft/sec² (1.52 m/sec²) until full speed of 39.5 ft/sec (12.04 m/sec) was reached. Retardation varied between 1 ft/sec² 0.30 (0.30 m/sec²) and 3 ft/sec² (0.91 m/sec²) and the creep speed into the decking position was 3 ft/sec (0.91 m/sec) and listed for 10 sec (see fig 35.1).

12 WIND (3). This was a repeat of wind (1) except that full speed was nominally limited to 35 ft/sec (10.67 m/sec) by the position of the power lever. Acceleration was uniform until the selected full speed of 35 ft/sec (10.67 m/sec²) was reached, when power was automatically removed and dynamic braking automatically applied. During the period of change speed rose to 37 ft/sec (11.28 m/sec) until dynamic braking became effective when speed reduced to 33.5 ft/sec (10.21 m/sec). Speed oscillations of this order continued throughout the full speed period and on one occasion during this period the winding engine was “free-wheeling” for 4 sec. Retardation was constant for the first 4 sec at 3.5 ft/sec² (10.21 m/sec²). Speed oscillations of this order continued throughout the full speed period and on one occasion during this period the winding engine was “free-wheeling” for 4 sec. Retardation was constant for the first 4 sec at 3.5 ft/sec² (10.21 m/sec²). Speed oscillations of this order continued throughout the full speed period and on one occasion during this period the winding engine was “free-wheeling” for 4 sec. Retardation was constant for the first 4 sec at 3.5 ft/sec² (10.21 m/sec²)

13 WIND (4). This was a repeat of wind (2) and produced similar results.
Figure 35.1 Test 1: Wind No 2. Recording of wind raising test load equivalent to 60 men

14 WIND (5). This was similar to wind (1) but with the test load in the other conveyance. Fig 35.2 shows the rate of acceleration to be uniform at 6 ft/sec² (1.83 m/sec²) and the winding engine to reach the full speed of 39.5 ft/sec (12.04 m/sec) in 6.5 sec. Full speed of 39.5 ft/sec (12.04 m/sec) was uniform throughout the period but an increase in speed was observed during the change from power to braking. Deceleration varied from 3.5 ft/sec² (1.07 m/sec²) to a maximum of 5 ft/sec² (1.52 m/sec²) for the first 7 sec, and at one point the winding engineman applied the mechanical brake to avoid tripping because of overspeed. For the next 9 sec deceleration was erratic and on occasions the winding engine was actually accelerating. Under the influence of dynamic braking speed dropped to 1.5 ft/sec (0.46 m/sec) 4 sec before the end of the wind. Braking was then automatically removed and power automatically applied, raising speed to 5 ft/sec (1.52 m/sec) as the conveyance reached the decking position, at which point the winding engineman applied the brake and removed power.

15 WIND (6). This was similar to winds (2) and (4) but with the test load in the other conveyance. The wind was uneventful until the winding engine speeded up at the end of the retardation period when the winding engineman removed power and applied the brake.

16 WINDS (7) AND (8). These were forward and reverse winds carried out in the manner of wind (1) but with empty conveyances. The only significant observation was the high landing speed of 4 ft/sec (1.22 m/sec).
TEST 2

17 The second installation to be tested was a parallel clutched drum winding engine used for winding coal. Its technical particulars are:

GEC 3000 hp (2238 kW) 3.3 kV, 490 rev/min slipring induction motor, equipped with rotor liquid controller, dynamic braking, and a closed-loop supervisory control system.

Full speed: 42.3 ft/sec (12.89 m/sec).

Shaft depth: 641 yd (586 m).

Pay load: 6 ton (6.10 tonne) nominal (or 48 men when used for manriding: 3.6 ton (3.66 tonne)).

Conveyances: two double deck cages each weighing 11 ton 2 cwt (11.28 tonne) each cage to carry four mine cars.

Weight of each mine car: 12.5 cwt (0.64 tonne).

Duty cycle: acceleration 14 sec; full speed 33 sec; retardation 20 sec.

No balance rope fitted.

18 The GEC closed-loop supervisory control system and method of operation are identical to those described for the winding engine used for test 1 (paragraph 8 of this section).
Test 2 results

19 WINDS (1) and (2). The first two winds were carried out with empty conveyances and full speed nominally limited to 30 ft/sec (9.14 m/sec) by the position of the power lever. Acceleration was uniform at 4 ft/sec$^2$ (1.22 m/sec$^2$) until the selected full speed of 30 ft/sec (9.14 m/sec) was reached; during the ensuing full speed period variations in speed were noted and at the end of this period the speed rose to 39 ft/sec (11.89 m/sec). Deceleration was uneven, starting at 4 ft/sec$^2$ (1.22 m/sec$^2$) and dropping to 0.8 ft/sec$^2$ (0.24 m/sec$^2$).

20 WINDS (3) AND (4). These two winds were carried out with empty conveyances but with the winding engine running at nominal maximum speed. Acceleration and full speed were uniform throughout these parts of the cycle, but deceleration alternated from 5.5 ft/sec$^2$ (1.68 m/sec$^2$) to 1 ft/sec$^2$ (0.30 m/sec$^2$) until the cage reached a steady speed of 2.5 ft/sec (0.76 m/sec) for the last 5 sec before the landing was reached.

21 WIND (5). This was carried out with a test load equivalent to a full man load descending and an empty conveyance ascending. Fig 35.3 shows rope speed and rotor current throughout the wind. Acceleration was uniform at 4 ft/sec$^2$ (1.22 m/sec$^2$) until full speed was reached. The graph in fig 35.3 shows clearly boosts of power during the full speed period which resulted in erratic behaviour. Before the end of the full speed period, a speed of 43 ft/sec (13.1 m/sec) was attached and dynamic braking applied before the retardation zone was reached. Retardation was uneven, varying from 4 ft/sec$^2$ (1.22 m/sec$^2$) to 1 ft/sec$^2$ (0.30 m/sec$^2$) and the winding engineman applied the hand brake before the end of the wind as, in his experience, the winding engine would have tripped because of overspeed.

22 WIND (6). This was carried out with a test load equivalent to a full man load ascending and an empty conveyance descending. The wind was uneventful apart from a variation in full speed from 38 ft/sec (11.58 m/sec) to 40.5 ft/sec (12.34 m/sec) and a variation in the rate of retardation similar to wind (5).
23 WINDS (7) AND (8). These were similar to wind (5) but with the test load descending in the other conveyance. Similar results were obtained.

24 WIND (9). This was a normal coal wind and outlines clearly the control that can be realised when the winding engine is operating closely to its designed duty (see fig 35.4). This wind was carried out with a load of 7.9 ton (8.03 tonne) ascending (4 full mine cars) and a load of 2.5 ton (2.54 tonne) descending (4 empty mine cars).

Figure 35.4 Test 2: Wind No 9. Recording of wind raising a normal coal load 6 tons

Conclusions

25 It is evident that, even with good AC closed-loop control systems, the winding engines tested did not function satisfactorily with automatic control under varying load conditions. The worst features were erratic deceleration and high landing speeds which would have been uncomfortable for men riding in a cage and made accurate landing impossible.

26 The tests confirmed that, at the present state of technology, AC winding engines are not suitable for the automatic winding of men.

36 Suitability of DC winding engines with closed-loop control for automatic winding

1 Tests on DC winding engines are referred to in paragraph 144 of Part 1A of the Report. Results of the tests are given below.

2 While it has been accepted practice in many countries outside the UK to adopt automatic man winding on DC winding engine installations, and accepting that similar practices are adopted for lifts, it was still considered necessary to assess
the performance of DC winding engines in the UK. Tests were conducted on two DC winding engines both equipped with a system of closed-loop control, one powered from a mercury arc convector and the other from a Ward Leonard set.

**Tests**

**TEST 1**

3. The first winding engine tested was used for winding men and materials in twin shafts, with one conveyance in each shaft. It is a conventional drum winding engine with its motor supplied through a twelve phase rectifier transformer and two mercury arc rectifiers operating at 800V DC. Technical particulars are:

- AEI 800 hp (597 kW) 800V, 367 rev/min DC motor with separately excited field. The control system has closed-loop speed control with acceleration, retardation and overriding current limits.

  Retardation when approaching the end of wind is also controlled by cam gear with separate cams for men and material.

- Full speed 20 ft/sec (6.10 m/sec)
- Shaft depth 575 yd (526 m)
- Payload 40 men or 4.5 ton (4.57 tonne) of stone
- Conveyances two double deck cages one weighing 6 ton (6.10 tonne) and the other 5.2 ton (5.29 tonne).
- Duty cycle Acceleration 9 sec; full speed 75 sec; retardation 10 sec basic plus extension by cam gear.

4. The normal method of winding men is for the winding engineman to preselect an armature current before removing the mechanical brake. For the purpose of test winds he was instructed to apply an armature current of 1000 A and then to release the mechanical brake and push the power lever to the full speed position.

**Test 1 results**

5. WIND (1). This was carried out with empty conveyances. Acceleration was smooth at 2.19 ft/sec² (0.67 m/sec²) and a constant speed of 20 ft/sec (6.10 m/sec) was maintained throughout the full speed; there was no appreciable change in speed when the motor field changed over from driving to braking. Retardation commenced at 1.58 ft/sec² (0.48 m/sec²) reducing conveyance speed to 4.25 ft/sec (1.30 m/sec). Retardation then dropped to 0.30 ft/sec² (0.09 m/sec²) until a conveyance speed of 1 ft/sec (0.30 m/sec) was reached. Final landing speed was 0.60 ft/sec (0.18 m/sec).

6. WIND (2). This was a repeat of wind (1) but in the reverse direction and similar results were obtained.

7. WIND (3). This was carried out with a test load equivalent to a full man load descending and an empty conveyance ascending. Fig 36.1 shows the speed/time graph and state of the electrical system throughout the wind; and table 36.1 compares these results with those obtained from wind (1). It may be seen that performances with maximum load descending varies little from that with empty conveyances.
Figure 36.1 Wind No 3. Recording of wind lowering test load equivalent to 48 men

8 WIND (4). This was carried out with the test load ascending and an empty conveyance descending. During retardation the motor field varied because full braking torque was not needed to maintain the required rate of retardation. Variations in acceleration and retardation were comparable with previous tests and the low landing speed was maintained (see table 36.1).

9 From these and other test winds on this winding engine, it is concluded that, with retardation cam gear in use, a landing accuracy within a band of 1.2 inches (30.48 mm) can be achieved irrespective of conveyance loads in the normal range.

TEST 2

10 For comparison, test winds were carried out on a bi-cylindro conical drum winding engine used for winding coal and men. Speed is controlled by a GEC closed-loop system with current limit and a cam operated rheostat for supervisory deceleration. Technical particulars are:

- GEC 120/2040 hp (895/1522 kW) DC 53.7 rev/min motor, supplied at 425 V from a 1200 hp (895 kW) motor generator set
- Full speed 52 ft/sec (15.85 m/sec) coal; 30 ft/sec (9.14 m/sec) men
- Pay load 5 ton (5.08 tonne) or 44 men
- Shaft depth 429 yd (392 m)
- Conveyances two skips each weighing 5 ton 15 cwt (5.84 tonne)
- Duty cycle for men acceleration 18 sec; full speed 30 sec; retardation 42 sec.
- Duty cycle for coal acceleration 8 sec; full speed 18 sec; retardation 12 sec.
11. The normal method of winding men is for the winding engineman to move the power lever 1.75 in (44.45 mm) and then to release the mechanical brake so that the conveyances move away slowly. After one revolution of the drum, the power lever is moved to the full speed position. This method of operation was used with all loads in all the test winds and the resulting accelerations were substantially the same. The winding engine control circuit is set for coal winding. For manriding, a compromise setting is achieved by inserting a fixed resistance which lowers the maximum speed to 30 ft/sec (9.14 m/sec); the same acceleration is maintained and deceleration is governed by the same cams. As a result, the winding engineman has to control speed for the first part of the wind to avoid tripping because of overspeed; moreover, at the end of the wind the cams commence to decelerate the winding engine early resulting in a long creep period.

**Test 2 results**

12. Test winds were carried out similar to those described for Test 1 in paragraphs 5 to 8 of this section. Some overshoot in speed occurred during the full speed periods but, although retardation was erratic, the final creep speed of 2 ft/sec (0.61 m/sec) was the same for all loads. It was noted that the retardation pattern for a test load equivalent to the full man load descending was identical to that of the test load ascending. The limitations of response of this winding engine for man winding are because it is set for coal winding.

**Conclusions**

13. The behaviour of both winding engines under test confirmed that DC winding engines with a closed-loop system are suitable for winding men automatically provided that the engines are modified for automatic control and set for man winding.

**Table 36.1 Summary of results of Test 1**

<table>
<thead>
<tr>
<th></th>
<th>Winding empty cages</th>
<th>Lowering full man load</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Acceleration</strong></td>
<td>2.19 ft/sec²</td>
<td>2.2 ft/sec²</td>
</tr>
<tr>
<td><strong>Full speed</strong></td>
<td>19.75 to 20 ft/sec</td>
<td>20 to 20.25 ft/sec</td>
</tr>
<tr>
<td><strong>Hunting at balance</strong></td>
<td>± 0.25 ft/sec at full speed</td>
<td>± 0.15 ft/sec at full speed</td>
</tr>
<tr>
<td><strong>Retardation 20 to 4 ft/sec</strong></td>
<td>1.6 ft/sec²</td>
<td>1.6 ft/sec²</td>
</tr>
<tr>
<td><strong>Retardation 4 to 1 ft/sec</strong></td>
<td>0.3 ft sec²</td>
<td>0.3 ft/sec²</td>
</tr>
<tr>
<td><strong>Steady creep speed</strong></td>
<td>0.6 ft/sec</td>
<td>0.7 ft/sec</td>
</tr>
<tr>
<td><strong>Steady creep distance</strong></td>
<td>14 ft</td>
<td>14 ft</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Winding empty cages</th>
<th>Raising full man load</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Acceleration</strong></td>
<td>2.1 ft/sec²</td>
<td>2.1 ft/sec²</td>
</tr>
<tr>
<td><strong>Full speed</strong></td>
<td>19 to 19.25 ft/sec</td>
<td>19 to 19.25 ft/sec</td>
</tr>
<tr>
<td><strong>Hunting at balance</strong></td>
<td>± 0.2 ft/sec</td>
<td>No balance at full speed</td>
</tr>
<tr>
<td><strong>Retardation 19.25 to 4 ft/sec</strong></td>
<td>1.67 ft/sec²</td>
<td>1.87 ft/sec²</td>
</tr>
</tbody>
</table>
37 Visit to Germany: electrical aspects

1 Reference is made in paragraph 160 of Part 1A of the Report to a visit by five members of the Electrical Sub-Committee to Germany from 10 to 14 February 1975.

2 Purpose of visit. The purpose of the visit was to study electrical practices adopted in relation to winding of men in shafts and compare these with philosophies being developed by the National Committee.

3 Programme

<table>
<thead>
<tr>
<th>Date</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>11 February 1975</td>
<td>Visited Westfälische Berggewerkschaftskasse Seilprüfstelle,* Bochum, to discuss with Dr H Arnold and his staff current German regulations and practices.</td>
</tr>
<tr>
<td>12 February 1975</td>
<td>Visited Gneisena Mine (Ruhr Kohle) near Dortmund to see a modern winding engine control system employing a digitiser and electronic supervisory system of control.</td>
</tr>
<tr>
<td>13 February 1975</td>
<td>Visited Bad Grund lead and zinc mine (Preussag AG Metall) to see an automatic push button operated cage winding engine using digital system of control from a digitiser and tachogenerator.</td>
</tr>
<tr>
<td>13 and 14 February 1975</td>
<td>Visited Kaliwerk Heringen potash mine (Kali and Salz) to examine and discuss an eight rope skip winding engine in the Grimberg shaft.</td>
</tr>
</tbody>
</table>

Westfälische Berggewerkschaftskasse (WBK) Seilprüfstelle

4 Prior to the visit, Dr Arnold, Director of the Establishment, had been informed that the party wished to include the following matters in their discussion:

(1) Push button controlled winding engines for manriding:

(a) methods of control, particularly from cage, such as cable or radio;

(b) methods of operating and interlocking shaft and cage gates;

(c) overspeed and overwind protection;

(d) methods of handling unusually long loads, for example techniques for modifying overwind trip positions;

(e) supervision of push button winding engines;

(f) German incident and accident experience with push button winding engines.

(2) Winding engine braking philosophy and attitudes towards retention of electrical braking after an emergency trip.

* Seilprüfstelle = rope testing station
(3) Safety and brake initiating circuits provided to bring a winding engine safely to rest in the event of overwind, overspeed etc. German philosophy and safeguards in respect of component failure or circuit faults such as short circuits or earth faults. Segregation of safety and control circuits. German specifications for construction of safety circuits including minimum requirements for insulating materials.

(4) Problems of rope slip associated with the large number of Koepe winding engines in Germany and any practical means developed to detect positively the position of a conveyance through a wind.

(5) Any positive views on the provision of a circuit breaker in the main DC loop of Ward Leonard winding engines, with reasons for choice.

(6) Statutory testing of winding engines particularly push button types.

(7) Any accident or incident experienced in Germany which might be helpful to the National Committee’s deliberations on safety of winding engines.

5 Dr Arnold explained that WBK is a private organisation established by a law of 1863 which required owners of mines to provide a testing station and school. The present organisation dates from 1912 when its sole responsibility was limited to ropes because of the number of accidents involving ropes. This responsibility has now been extended to make safety assessments and to issue certificates as required by German regulations for complete winding installations including shaft equipment. Underground transport systems are dealt with in a similar way. A certificate is required before a new installation can be put to work or when a major change is made to existing winding and shaft systems. The whole of each winding system seems to be examined in great detail including specifications and equipment possibly employing destructive and non-destructive testing. Annual examinations of certificated installations are also made by WBK staff and, in this respect, they are responsible for some 400 main shafts, 600 staple shafts and a number of underground transport systems.

6 The establishment is considered a neutral organisation and half its income comes from fees for work done and half from members who include mine owners and manufacturers. There are sixty-five employees, the majority of whom carry out tests and make inspections on site.

7 German regulations require that mechanical brakes are automatically applied as a result of an emergency trip. The mechanical braking may be regulated for certain trips but is required to be fully applied when necessary near the end of the wind. These arrangements are required for friction winding engines which form the commonest type in Germany. Electrical braking is not retained when mechanical brakes are automatically applied as a result of an emergency trip.

8 The present winding regulations (Mining Regulations for Main Man Winding Installations – issued by the Chief Mining Inspector, Dortmund 1 August 1957) came into force in 1957 and are considered to be out of date. It is expected that new regulations will be introduced at the end of 1975 or early 1976. The Government consults the establishment on proposals for new regulations and it is expected that these new regulations will impose progressively more arduous testing as tonnages handled increase.

9 With regard to checking conveyance position throughout a shaft, Dr Arnold advised that as proximity switches give all the information considered necessary no work on continuous monitoring is proceeding. In Germany, because only fixed guides are used, the use of proximity switches is satisfactory in any position in a shaft.
10 When assessing an installation, only spot checks are made on the main structures as it would not be possible to examine the complete design, because of limitations in manpower.

11 The establishment accepts responsibility for work carried out by its staff but is covered by insurance; this cover has only been used once. Staff authorised to sign certificates of approval have a diploma in engineering, have served some five years in the industry and have had two to three years training at WBK. Mention was made of the British Health and Safety at Work etc Act 1974 which places responsibilities on manufacturers as well as management and owners. In Germany it is proposed to make the owner more responsible but this will mean that more trained and qualified staff will be needed.

12 Consideration is being given to the provision, for each large winding engine, of crack detection equipment in the winding engine house and, as a further safeguard, the possibility of fitting permanent strain gauges at critical points on brake gear.

Winding engine braking philosophy – retention of electrical braking

13 Electrical braking is not required by German regulations and universal practice in the event of an emergency trip is to remove power and retard solely by the mechanical brakes. Each winding engine has two brake engines, one is for service duty and the other is the emergency safety brake; but they operate on the same brake shoes and paths often through common mechanisms. Failure of such single line components has occurred but never with catastrophic consequences. Since the Markham accident non-destructive testing of single line components has been increased and extended and is likely to be a requirement of the new regulations now being drafted. In the case of AC winding engines, switches in the safety circuit do not trip the stator contactor until the brakes are proved on by using a limit switch operated by movements of the dead weight or springs in the brake system. The AC winding engine is used for comparatively light duties in Germany. The AC motor is not a favoured form of drive because accurate speed and position control are more difficult to achieve than with a DC machine. Dynamic braking is not commonly in use.

Safety circuits

14 German practice, as understood by the visiting party, is as follows. On AC winding engines with normal maximum rope speeds not exceeding 6 m/sec, a simple overspeed device is used which causes the safety brake to operate at speeds greater than 115% of full speed. On AC winding engines with normal maximum rope speeds exceeding 6 m/sec, a speed controller is installed in addition to the simple overspeed device. The speed controller causes the service brake to operate when speed rises to 110% of full speed to restore normal speed. On DC winding engines with closed-loop control, no overspeed device need be installed; but, in the case of open-loop control, a contrivance is used to enforce retardation of the winding engine at the end of a wind. The contrivance is usually referred to in the German mining industry as the ‘mine winder controller’ (Fahrtregler).

15 All large winding engines have closed-loop control and three methods of protection are used:

(1) Speed control imposed by the closed-loop (normal control).

(2) Electrical supervision of the control loop. This is achieved by using a further tachogenerator driven by the rope sheave or drum and comparing its output in a comparator circuit with the output of the tachogenerator used in the closed-loop control.
(3) An automatic contrivance which can be mechanical or electronic.

16 For each of these three methods of protection, magnetic proximity switches are installed in that part of a shaft where retardation normally occurs. There are usually four switches, one being for final alignment of the conveyance. When an electronic or digital method is employed for indicating and controlling the position of a conveyance in a shaft, a fifth switch is used; it is positioned just before the retardation zone to synchronise the digital system to effect rope creep compensation.

17 It is not practice in Germany to use screened cores for interconnecting cables in the safety circuit but care is taken to minimise risks of faults which could cause dangerous malfunctioning. It has been practice for many years to provide earth leakage protection on the system as a whole. It is also practice to use two safety contactors and two brake solenoid valves. These devices are supervised to ensure that they are operating correctly.

18 It is suggested that the new German regulations may contain features which will be relevant to the work of this Committee. At the present time, however, there is no detailed specification for safety circuits as their design is agreed between manufacturer and customer.

**Rope slip and conveyance monitoring**

19 It is claimed that rope slip is not a major problem; and that when creep occurs it is corrected by a device on the controller or by a proximity switch in the shaft when a digital system is used. It is not considered necessary for safety to monitor a conveyance throughout a shaft when use is made of proximity switches in the retardation zone. Operation of these switches is compared with the supervisory system and if there is any discrepancy the mechanical brake is applied. If overspeed is less than 120% of normal full speed, the service brakes comes into operation and is released when the winding engine is back to normal speed. If however overspeed is more than 120% of normal full speed, the emergency brake is applied and the winding engine brought to rest.

20 Information was received that a system of monitoring the position of a conveyance in a shaft is in use in France in Houillères du Bassin de Lorraine, Freyming-Merlebach and further information is being sought.

**Use of circuit breakers in DC loops**

21 There appears to be no accepted practice in respect of the use of high speed circuit breakers in DC loops of Ward Leonard winding engines. No arguments were put forward for their use or omission. Each German manufacturer adopts his own standard; for example, AEG use a circuit breaker but Siemens and BBC do not. All manufacturers use a circuit breaker when thyristors are used as the source of variable voltage DC.

**Testing of winding engines**

22 The training of WBK personnel authorised to sign certificates was briefly discussed. For the inspection of winding engines, it was stated, the qualifications required are the minimum of a Diploma in Engineering, some five years training in the industry and two to three years with WBK which form a long and arduous course.

23 The initial assessment, tests, and subsequent reassessment if a major change is required, are carried out by WBK. A statutory document has to be prepared containing:
24 The signalling system for a winding engine is considered of great importance and details such as specified in 23(1) to 23(5) above for the winding engine system are included for the signalling system. Finally the document has to be signed by representatives of WBK, the mines inspectors and manufacturers, and by the mine manager on behalf of the owners.

25 Certain examinations and tests of winding installation are required by law. Once a year, within a period of 12 to 15 months engineers from WBK return to a mine and carry out checks on a winding engine against the original commissioning documents as follows:

(1) the cycle;
(2) the control system;
(3) the retardation rate;
(4) brake response;
(5) a complete examination of the signalling system.

26 These examinations and tests take, on average, about six hours and are recorded and signed for in a statutory book. The necessary instrumentation and equipment for tests are taken to mines by engineers of WBK but there are plans for some test instruments to be incorporated in winding engines.

27 A mines inspector examines the condition of a shaft and shaft installation once a year and checks at the same time that an annual inspection of the winder system has been carried out by engineers of WBK.

28 Intermediate daily, weekly and monthly examinations are carried out by appropriately qualified mine staff or, in some cases by law, by persons authorised by the mines inspectorate from an independent testing organisation eg TUV. This system results in division of responsibility which the visitors considered inadvisable; but there could be advantages in thorough periodic examinations, say every two or three years, by a competent independent organisation.

29 At the present time, no non-destructive testing is required by regulation but this is expected to be changed in the near future. Without prejudice to the new regulations, it is also proposed to carry out non-destructive tests on single line components of braking systems at the next annual examination of each winding engine. This action has been prompted by the Markham Official Report.

Incidents of interest

30 Two incidents of interest involving electrical components were related. In one case, grease on the contacts of a brake solenoid contactor caused a delay of four
seconds in de-energisation of the brake solenoids resulting in an overwind. In the second case, a fault in the winding engine motor field system caused a conveyance to run into tapered guides at a speed of 12 m/sec.

**Push button control of man winding**

31 In Germany automatic winding of men with push button control is not specifically prohibited. This subject was not discussed in detail but reference is made to it later in this section in relation to visits to winding installations.

**Gneisenau Mine of Ruhrkohle, Dortmund**

32 Gneisenau Mine is the largest in the area and the skip winding installation seen raises 25,000 to 28,000 tonne per day, the monthly output being around 380,000 tonne. The winding engine, which is a twin rope Koepe tower installation, was first commissioned in 1962, the motor at that time being rated at 3150 kW and supplied from a 12 phase mercury arc rectifier system. The payload was then 17.5 tonne. Some time later, the payload was increased to 20 tonne and, to wind this, forced cooling was applied to the motor. In 1973, the payload was raised to 23 tonne. Increased output from the motor was achieved by fitting a new armature bringing the rating of the machine up to 4000 kW. At the same time, the insufficiently rated mercury arc rectifiers were replaced by thyristors and a modern solid state control system with an overall programme controller (Siemens type S3). It was claimed that the changeover took only eleven days. If the more conventional relays had been installed for the control and protective systems, it is estimated that a further eleven days would have been needed because of extra cable work necessary.

33 This particular programme controller can accommodate 953 digits and the desired programme can be typed into the equipment. A brief statement on the advantages, and a description of the control computer and winding engine digital controller have been abstracted from an article by Dipl Eng G W Barlow of Siemens on Winder Installations and are quoted below:

**Control computer**

Modern winding engines are controlled by a free programmable control computer. The adoption of a computer for control purposes has been made possible by the use of relatively inexpensive integrated circuit components, ie a large redundancy of components is economically acceptable. The free programme computer reduces substantially the amount of wiring needed compared with conventional techniques. A further advantage is the possibility of altering the control programme at any time without additional wiring or alterations in wiring. The work required in preparing drawings is also substantially reduced. The computer system requires only function diagrams instead of the circuit diagrams needed for conventional techniques.

**Winding engine digital controller**

Ever increasing shaft depths have necessitated development of a fully electronic winding engine controller. The conventional mechanical cam mechanism winding engine controller can be used through an angle of rotation of approximately 320 degrees. The accuracy of the simulation scale is therefore diminished in deeper shafts. The electronic winding engine controller represents the shaft depth digitally with great accuracy. A shaft angle digitiser, normally directly coupled to the winding engine drum, converts drum rotation into a train of electrical pulses. The shaft angle digitiser has a non-magnetic disk, bearing a
layer of magnetisable material on the outside. This layer is magnetised with alternating polarity to produce magnetic cycles which are scanned by two Hall generators. The number of magnetic cycles can be selected to provide the desired length of shaft travel per pulse. Pulses from the shaft angle digitiser are counted in an electronic counter. The contents of this counter are used to control stopping and starting of conveyances at intermediate levels, the deceleration being controlled by an auxiliary deceleration counter which starts to count down when a particular counter reading is reached. For the end positions, the main and deceleration counters are synchronised by conventional magnetic type shaft limit switches. The deceleration counter reading is converted into an analogue signal for controlling the speed reference for the winding engine closed-loop control so that desired deceleration is maintained. During deceleration for the end positions, the resulting analogue signal from the deceleration counter is checked at fixed points selected by further magnetic shaft limit switches. Discrepancy between the analogue value from the deceleration counter and the check value initiates emergency braking. At the same time, speed of the winding engine measured by a tachogenerator is compared with the analogue signal from the deceleration counter and any discrepancy initiates emergency braking. It is also possible to provide a back-up deceleration counter set by a magnetic shaft limit switch mounted adjacent to the synchronising switch in the end of wind zones. The outputs of both deceleration counters can then be compared to test whether malfunctions exist in either the shaft limit or the electronic counters themselves. Another feature of the fully electronic winding engine controller is that the depth indicator can be operated also from the shaft angle digitiser pulse trains. The depth indicator in this case is equipped with a pulse stepping motor.

34 The controller is used to check the state of protection transducers and can be used to control type of braking, that is electrical or mechanical, on operation of a transducer relative to the position of the conveyances in the shaft. It does not, however, replace the mine winder controller which is required by law. Information about the position of the conveyances in the shaft is obtained from a digitiser driven through a gear box from the drum shaft. The gear box seems to be a single line component but is necessary as only two pulses per revolution are obtained from this unit and a pulse is required for every centimetre of travel of a conveyance in the shaft. The pulses are obtained by means of Hall plate transducers.

35 Maximum speed of the conveyances is 16 m/sec but men are wound under manual control at a maximum speed of 8 m/sec. Operational experience has been good: there have been no breakdowns since installation was completed. The mine engineer indicated that they were satisfied with the system and he would be quite prepared to use it for push button winding of men. A similar system for a man winding shaft, using two cages and working to five levels, is on order and should be commissioned in 1976. A test programme to find the cause of a stoppage and so speed up fault finding is available for the programme controller.

36 As the winding engine works twenty hours per day, the maintenance programme has to be carefully planned to include all mandatory inspections and others considered essential as a result of experience. Check lists for each inspection have been formulated to assist in the work.

37 A point of interest is that it is necessary to provide a battery operated inverter which comes automatically into operation on loss or fall in supply voltage so that the electronic equipment continues to operate in a satisfactory manner.

38 The load sharing of the main thyristors is achieved by critical lengths of lead appropriately formed into specifically spaced groups. The position of each group...
with respect to the next is adjustable to ensure good load sharing. The arrangement occupied considerable space on one floor of the tower.

39 The winding engine was manually operated for man winding, shaft inspections, and similar duties, and the control desk is situated on the top floor of the tower. During coal winding, the winding engineman sat in a small cabin at the skip discharge point checking that discharge was effective. Environmental conditions in this cabin are not as good as in the winding tower. Communication from skip to winding engineman is achieved by means of an inductive loop radio system which provides facilities for signals and speech.

**Bad Grund mine of Preussag A G Metall**

40 The product of Bad Grund Mine is lead and zinc ore and is wound up a shaft in small mine cars. Access is at eleven levels since the ore lies in a seam at 15 degrees from vertical. For normal winding, both cages are used between the top and bottom of the shaft. Intermediate levels are only serviced by one cage. The pit top tub circuit comprises a traverser shunt back and tippler, and is controlled by a banksman from a cabin near the shaft. The banksman operates also winding engine control push buttons mounted on his desk. It seems that men and ore can be wound at the same time. It was noted that men travelling from one level to another were wound on the top deck of a cage to the surface where loaded cars on the bottom deck were exchanged for empty cars; and the men were then lowered to the desired level. The winding engine is a ground mounted single rope friction driven plant which has replaced a bi-cylindro conical drum DC winding engine incorporating a conventional Ward Leonard motor generator set. The disc type brake and electrical portion were manufactured by Siemens. Four disk brake units are used which embrace the full width of the friction sheave.

41 Each brake mechanism on each side of the sheave is fitted with:

1. a wear switch which operates when adjustment of the brake becomes necessary;
2. a wear switch which operates when replacement of a pad becomes necessary;
3. a switch which operates to indicate whether the brake is on or off.

42 The sheave is driven by a 1240 kW direct coupled overhung DC motor fed via a variable thyristor. The control is similar to that at Gneisenau without the programme controller. The digitiser on the sheave shaft is again driven through the gear box but is more complex than that at Gneisenau and has a second set of pulse generating elements to feed an electronic supervisory system (Siemens Simatic ‘N’ system). As a headframe is used, rope slip protection is provided by comparing the output of the closed-loop tachogenerator driven by the friction sheave with that of a tachogenerator driven by one of the headframe pulleys. The installation is neat and compact for its rating; but cubicles were open at the bottom and dusty inside which would not in general be acceptable.

43 A test is provided to enable a check to be made on performance of the Siemens Simatic System. By plugging into the system at appropriate points, the equipment can quickly be checked for correct operation. In the time available a detailed understanding of the procedures was not possible; but the mine engineer said he had been highly satisfied with the installation throughout the one and one half years it had been in operation.
Heringen potash mine of Kali and Salz

44 At Grimberg shaft, an AEG eight rope tower mounted friction winding engine hoists skips of 25 tonne payload. Men are wound on three decks situated below one of the skips only (each deck capable of accommodating 22 men) under push button control. These decks have cage gates. The friction drum is driven by a 4200 kW direct coupled DC motor supplied via thyristors. The thyristors are forced cooled and load sharing is ensured by one choke per thyristor unit and not by the use of coupled groups of leads as adopted by Siemens. Forced cooling of the winding engine motor is employed and is carefully engineered; a closed circuit is used but air is leaked from the commutator to remove any carbon dust from the brush gear and prevent ingress of foreign matter. Carefully filtered air replaces the loss.

45 It was noted that the whole friction drum is enclosed to prevent ropes etc from carrying salt crystals and dust into the winding engine house on the top two floors. Mechanical braking is achieved by means of an ASEA, disc brake operating on two discs: there are six units, each comprising two pads per disc. Limit switches are fitted to initiate indication of:

1. wear requiring adjustment;
2. wear requiring change of pads;
3. whether the brake is on or off.

46 The winding engine operates automatically for twenty hours per day, seven days per week. Mineral for Saturday and Sunday winding is obtained from a large underground storage bunker.

47 The system of control is different from those previously described in that a mine winder controller is fitted which performs a number of functions. It is driven from the friction drum shaft by a chain drive which is monitored by comparing output of the closed-loop tachogenerator with the output of a tachogenerator driven from within the controller. A differential is incorporated in the drive for creep correction. The rope creep compensator drive motor is energised if a proximity switch at the shaft landing position is operated with the appropriate overwind switch in the open position. Movement of cam levers is transmitted to the control system from the controller by means of selsyns. Loss of supply to selsyns trips the winding engine. The controller is fitted with:

2. A cam which provides for supervisory monitoring of the closed-loop control.
3. A number of adjustable pegs mounted on a drum of some 0.6 m diameter which is on the same shaft as the Ward Leonard cams. The pegs perform the function of overwind switches and positively drive robust maltese cross auxiliary switches.
4. Two small selsyns which drive the depth indicators on the driver’s control desk.

48 Doubt was expressed as to the security of the method of fastening pegs to the drum, bearing in mind that they have to be capable of continuous, not stepped, adjustment. The method of securing is by means of two small hexagon headed bolts clamping each peg to a T sectioned groove in the drum.
49 The control system is a mixture of solid state and relay circuits. It appeared that, for instance, while duplicated solenoids are used for initiating application of the brake, their correct functioning depends upon opening of a single contact in a single relay. Furthermore, investigation of the safety circuit diagram revealed that there are about ten safety relays in parallel, each performing a separate function, eg initiating brake application, removing power etc. This arrangement appeared unnecessarily complex and not as reliably fail-safe as the British double safety contractor arrangement. Without further detailed investigation this would seem contrary to our present philosophy: but when a description in English of the winding engine is available, a better understanding will be possible of the principles involved.

Push button winding of men

50 At the surface man landing, there is a panel on which are mounted a number of luminous indicators and key operated switches. The switches are for:

(1) normal man winding;

(2) shaft inspection;

(3) rope inspection;

(4) calling the skip to the landing.

51 Insertion of a Yale type key into the appropriate switch enables the desired duty to be selected. After operating the switch, the key can be removed locking the switch in the selected position. Speed of the conveyance is restricted according to the duty selected: 15.5 m/sec for mineral, 10 m/sec for men, 0.5 m/sec to 0.2 m/sec for shaft inspection, and 0.5 m/sec to 1 m/sec for rope inspection.

52 If it is required to wind from the man landing, then a key switch has to be operated to bring the skip to this landing. The winding of men is achieved by operating a further key switch in the appropriate manner and withdrawing the key. This sets up the winding engine so that the maximum speed for man winding is not exceeded and the necessary circuitry on the mine winder controller and the shaft switches are brought into operation. To enable push button winding to be controlled from the skip, and communications to take place between the skip and the surface, an inductive loop radio system is employed. The equipment on the skip is fed from a battery and is normally in a quiescent state when mineral winding. Operation of the key switch also causes this transmitter/receiver to become operational.

53 The external shaft gates at the various levels are electrically interlocked by means of magnetic proximity switches but are not mechanically locked. Opening of a gate with the conveyances in motion causes the emergency brake to be applied. The push button system within the cage section of the skip enables levels to be selected as in lift practice.

54 The management of the mine have been well satisfied with the winding engine throughout the three or four years of its operation during which it raised 20 million tonnes with negligible down time owing to faults or breakdowns. AEG engineers expressed the opinion that DC machines can be controlled and protected more effectively than AC types. They also felt that a winding engine with a three level control comprising conventional closed-loop control, continuous automatic supervision of the closed-loop system, and overall protection by a mine winder controller or automatic contrivance, is preferable to one with closed-loop control and with an automatic contrivance plus supervisory device.
55 AEG have not developed a system for monitoring the position of conveyances throughout the shaft, but considered the control and supervisory system on the Grimberg winding engine equally effective. Using proximity switches in the deceleration zone in the shaft, conveyance position is checked both when approaching and leaving the surface; further checks are provided via the surface proximity switch in association with a rope creep compensator, and by visual indication at the control desk.

**Observations on visit**

56 The three winding engines seen employed complex control and supervisory systems and it was not possible in the time available to study these in detail. However the visit was useful as it was possible to get an impression of German winding practices and philosophies, and the following is a summary of the more significant points:

1. No aspect of German practice and philosophy would suggest the necessity for radical changes in philosophies developed by this Committee.

2. The long established German practice of having a manual for each winding engine and a form of safety assessment endorses proposals in this Report.

3. Sections 17 to 20 concerning safety circuit philosophy seem more thorough than anything yet conducted in Germany although advantages to be gained from earth fault protection or alarm have long been recognised there.

4. It may be worthwhile to compare the three level control, supervision and protection philosophy with the philosophy of closed-loop control and an automatic contrivance plus supervisory device. For the three level system to be effective, however the supervision and protective systems must be as independent of each other and of the control system to avoid common mode failure. This Committee is not convinced that the necessary degree of independence is achieved in the German systems seen.

5. Push button winding of men, using inductive loop systems for control from the cage, appear to be operating effectively and a more detailed study of these systems may be worthwhile if similar systems are to be tried in British mines.

6. Some German mines operate a system of winding engine defect reporting. In some cases they send a copy of the report to the manufacturer, in other cases they keep a log book of all defects experienced. This promotes monitoring of performance and helps the manufacturer to design out defects or shortcomings that might affect safety.

7. German engineers have a clear preference for DC winding engines on account of accuracy of control and relative ease of protection.

8. New German winding regulations are being prepared in North Rhine-Westphalia and will be worthy of study when published.

**Acknowledgement**

57 The visiting party are grateful for the courtesy extended by the German engineers at all places visited and for the opportunities made available for frank discussion of winding safety.
38 Visit to Germany: mechanical aspects

1 In Part 1A, paragraph 160, reference is made to visits to Germany to discuss German winding practices with particular regard to safety. A list of questions was submitted to the German authorities prior to the visit of the mechanical engineering team and this is shown at appendix 38.1. Shortly before departure, a translation of German Manwinding Regulations became available and this obviated the need for some questions while assisting in the direction of others. The itinerary included a full day’s visit to the WKB\(^4\) Rope Testing Station (Seilprüfstelle) at Bochum, one full day at the Tremonia Experimental Mine, Dortmund, half a day at Gneisenau Colliery, Dortmund, and a half day at Grimberg Potash Mine near Heringen. The mine visits were made in collaboration with the winding engine manufacturers, Siemens, GHH and AEG, so that there were opportunities to discuss design and control matters in addition to operational and maintenance aspects of winding installations.

Types of winding equipment

2 In West Germany, friction engines are installed at nearly all mine shafts. Experience with drum winding engines as commonly used in the UK appeared to be limited, eg in North Rhine – Westphalia (Ruhr and Aachen coalfields) there are 329 friction winding engines currently operating compared with 57 drum winding engines and 28 bobbin reel type winding engines. The latter are said to operate at only small, light duty shafts.

3 The manwinding regulations apply to all types of winding engines so that overwind distances and requirements for headframe arrestors apply equally to drum and bobbin winding engines as well as friction winding engines. Detaching hooks are not used. Stranded winding ropes and ropes of flat construction are in general use. Ropes of locked coil construction are uncommon. With few exceptions, balance ropes are of flat construction and flat ropes are also used on bobbin winding engines. Average depth of shafts is 802 m. Because of limited clearances and deviations from vertical, rigid guide systems are widely used. Research work is currently being carried out at Tremonia Mine to analyse stresses imposed on guides and rollers under various dynamic conditions.

Regulations

4 Regulations relating to the design and installation of winding engines are made by the Chief Mining Authority (CMA) at Dortmund, which incorporates the mines inspectorate. The regulations are issued in two parts, vis:

(1) Bergverordnung des Oberbergamts in Dortmund für Hauptseil-fahrtanlage dated 1 August 1957, which relates to main winding installations.

(2) Bergverordnung des Oberbergamts in Dortmund für Mittlere und Kleinere Seilfahrtanlagen dated 1 February 1960, which relates to medium and small man winding installations.

Design and installation

5 Man winding equipment may only be installed on receipt of a written permit from the CMA. Alterations to the equipment similarly require approval as do repairs and replacements unless they are of the same material, construction and strength as the originals (see appendix 38.2). Winding engines must be equipped with

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\(^4\) Westfälische Berggewerkschaftskasse.
brakes whose design has been approved by the CMA. The design criteria for winding engine brakes and brake components are given in appendices to the regulations mentioned in paragraph 4 of this section and also in DIN numbers 22403, 22404 and 22406.

6 From the standards examined and discussions held, it would appear that only static load criteria are used for component design of brake gear. There does not appear to be any immediate intention of introducing fatigue criteria into the regulations governing brake design. Single line and screwed components of brakes are now being considered in relation to possible fatigue failure and new designs of such components are evidently required to withstand fatigue testing between $2 \times 10^6$ and $10 \times 10^6$ cycles before the design is considered to be acceptable. Brake rods require to have a minimum factor of safety of 5 in relation to the maximum operational braking force applied, i.e. from either the service or emergency brake. Where the total braking power of brakes can be combined, rods are required to have a factor of safety of at least 3. All threaded components in winding engine brake systems must have round threads in accordance with DIN 20400. Anchor bolts in the fulcrum bearings of brake shoes require a factor of safety of 7.5 and in the case of the combined braking mentioned above the minimum factor of safety is 4.5.

7 Regulations require the material for a particular component of winding apparatus to be stated by the manufacturer, but do not specify the material. WBK study and advise on materials which may be specified for various brake components. For critical components, fully killed steels with guaranteed notch ductility are demanded. For other components, reliance is placed on manufacturers to test materials and ensure that components are free from manufacturing defects. Detailed information obtained in respect of materials selected for mechanical parts of brakes is in appendix 38.3. The general approach in Germany appears to be to select plain carbon steels as much as possible but to ensure that these are purchased to a high quality within the specification ranges.

8 Friction winding engine regulations in Great Britain require the calculated retardation to produce slip to be based on a coefficient of friction of 0.2 between rope and rope tread material. The comparable figure used in Germany is 0.25. Friction winding engines in Germany are fitted with approved treads which are mainly forms of PVC. These are preferred to natural materials because they give more consistent friction values. Approved tread materials include: Kautex (W Oxe); K.25, D.670 – aluminium, (Becorit); Tekaplast, Küper) and F.2 (J Becker). The materials must give a minimum coefficient of friction of 0.25 in dry, wet and lubricated rope tests. Experimental work is done at WBK to establish acceptable combinations of rope lubricants and tread materials. The coefficient of friction is determined on a test rig in which rope is sandwiched between two loaded friction treads and measurement taken of the force necessary to pull the rope through them.

**Control and brake equipment**

9 Winding engines with a designed rope speed of 6 m/sec or less, must be fitted with safety apparatus to prevent the maximum speed from being exceeded by more than 2 m/sec and to limit the speed past landing to half man speed or less. The safety apparatus operates to remove power and apply the emergency brake.

10 Winding engines with a designed maximum rope speed greater than 6 m/sec require to be fitted with a mine winder controller (Fahrtegler) to prevent the maximum speed from being exceeded by more than 2 m/sec and prevent speed past landing from exceeding 4 m/sec when winding men or materials.

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5 *Deutsche Industrie Norm (German Industry Standard)*
11 In the case of open-loop DC winding engines, retardation cam gear forms the mine winder controller and, for closed-loop DC winding engines, it is the speed control system incorporating retardation control by cam gear or other means. In the case of AC or steam winding engines, the mine winder controller operates to maintain the winding cycle by reducing power and applying the service brake (not the emergency brake) automatically should the winding engine tend to overspeed. In all cases, power is removed and the emergency brake applied should speed exceed the pre-set cycle approximately by 10% or when an overwind occurs. This appears to be a major difference from British practice in which the automatic contrivance functions to stop the winding engine in the event of overspeed by removing power and applying emergency braking.

**Maintenance and testing**

12 The itinerary and scope of interests of members of the party limited time available for consideration of colliery maintenance organisation; and it is not possible to draw general conclusions from half-day visits to two modern winding installations. Nevertheless, it was possible to make a few general comparisons of German and British practices and to obtain views of experienced specialists on some common problems.

13 Procedures and documentation in winding engine and winding rope report books required by German regulations appeared to be similar in principle to statutory books used in Britain. The German report book appears to be more comprehensive and to provide a more integrated record. This is to be considered in detail in relation to a concept of a winding engine log book. German regulations are basically similar to British regulations in requiring records to be kept of defects and reports to be made of incidents. Important damage, major defects and incidents are required to be reported immediately to the German inspectorate and other damage must be reported after one week if it has not already been repaired. Annual reports are issued by the Chief Mines Inspector; and winding engine specialists at WBK maintain their own records of failures.

14 No routine non-destructive testing was carried out on brake parts at the three mines visited. However it was understood that WBK had proposals to introduce periodic non-destructive testing of mechanical brake parts whose failure would be potentially dangerous. Components would be divided into two classes:

(1) Components whose failure would result in complete loss of braking. These would be examined every year and the mine would hold spare parts for replacement.

(2) Components whose failure would result in some loss of braking force. No frequency of testing has been decided but it would be related to loss of braking force following failure.

15 At the two operational mines visited, maintenance of winding systems was administered by engineers who appeared to be roughly equivalent to British deputy colliery engineers. At the potash mine, the engineer in charge was responsible for both mechanical and electrical equipment and he had mechanical and electrical shift charge engineers reporting to him. Both winding installations visited appeared to be well maintained although it was said that difficulty was experienced in obtaining adequate time for maintenance. It was also intimated that absenteeism among maintenance staff has caused difficulty.

16 At Gneisenau colliery, the daily output of approximately 25,000 to 28,000 tonne from a combined mine is wound at No 3 shaft in balanced 23 tonne capacity skips
by means of a twin rope, tower mounted, friction winding engine. Time allocated for
maintenance is two hours in each of the five working days of a week; and, although
some winding is done at weekends, the period from 08.00 on Saturday until 20.00
hours on Sunday is also made available for maintenance and testing. The average
life of the winding ropes is 11 months.

Research and experimental work

17 WBK is financed partly by the German mining industry and partly by a
Government subsidy. German law requires the industry to carry out research,
testing and training with the objective of improving safety in mines, and this was the
origin of the institute. A translation of the working programme of WBK for 1975 is in
appendix 38.4.

18 Brief summaries of the facilities and the scope of work carried out at the
Seilprüfstelle (rope testing station) Bochum, and the Tremonia Experimental Mine,
Dortmund, are in appendices 38.5 and 38.6 respectively. In addition to laboratory
work on ropes and brake gear etc, the Rope Testing Station carries out important
field work. Twelve engineers form a testing staff who are employed on winding
engine performance testing in the Ruhr District and, in certain special
circumstances, elsewhere in West Germany.

19 An instrument for non-destructive examination of wire ropes was developed
many years ago at the Seilprüfstelle. It is similar in principle to the Polish MD6
instrument already tested by MRDE\textsuperscript{6} and SMRE\textsuperscript{7} but incorporates four search coils
from which, it is claimed, the position of broken wires in a rope can be determined.
From experience gained of non-destructive testing and subsequent rope
examination, the percentage loss in strength due to broken wires, corrosion and
wear can be sufficiently accurately assessed from records to enable the
instruments to be used for deciding when ropes should be withdrawn from service;
the criteria used are 10 to 14% loss in strength or ten wire breaks per metre length
of rope. No difficulty is experienced in matching records with later examination at
slightly different rope speeds. Experience to date is mainly with stranded ropes but
the opinion was expressed that the instrument would work equally well with greasy
locked coil ropes.

20 A similar instrument has also been developed for examination of underground
haulage ropes. For underground use by rope examiners, this instrument
incorporates simple visual indicators of percentage loss in rope strength instead of
a chart recorder.

21 A transducer has been developed to measure loads in tie rods of winding
engine brakes. The results are displayed digitally in the engine house. The device
has been successfully used at Tremonia Mine to ensure equal loading in twin brake
assemblies and to assess efficiency of the transmission system between the brake
ingines and tie rods. Brake torque reaction devices are not used but such devices
are being studied.

Training

22 German regulations require that winding enginemen be trained in accordance
with a syllabus approved by the CMA (see paragraph 4 of this section). This was
discussed at the Rope Testing Station at Bochum. Winding enginemen are

\textsuperscript{6} Mining Research and Development Establishment, National Coal Board.
\textsuperscript{7} Safety in Mines Research Establishment, Health and Safety Executive.
apparently recruited from colliery engineering staff and are required to have had six months’ experience as banksmen or onsetter before being trained as winding enginemen. Training on the job is augmented by a one week course of instruction at WBK during which a typical programme would include the following:

- AC and DC winding engines principles: 1 day
- Winding engine brake systems: 1 day
- Signalling systems: 1 day
- Controllers and safety devices: 1 day
- Discussions, which may be held at a winding engine installation: 1 day

23 Trainees are tested and examined by WBK specialists at the winding engine which they are to operate and are issued with a certificate of competency for a particular winding engine. For operating a different winding engine, winding enginemen must be examined following an additional six weeks period of on the job training for re-certification.

Conclusions

24 The main purpose of the visit, and the main theme of discussion throughout, was to determine whether anything is done at German winding installations which could be adopted to improve safety of man winding at British mines. In the short time available, it was not possible to make much more than a general appraisal of a few aspects of German winding practices. Nevertheless, the consensus of opinion of the delegation is that none of the winding practices or associated mechanical apparatus seen or discussed represents a significant improvement in safety over those already employed at mines in Britain.

25 Much useful development work is being carried out in Germany and it would be imprudent not to keep in touch with this work. It is considered that the following matters merit further detailed investigation:

1. Non-destructive testing of ropes with the German Defectorgraph.
2. Detailed comparison of disc brakes with conventional shoe brakes on winding engines.
3. Visual indication of forces in brake tie rods.

26 Although the request was made, it was not found possible during the visit to arrange a meeting with the winding specialist of the German Inspectorate. It is clear that the Mines Inspectorate in Germany are involved not only with investigation and recording of winding engine incidents and mishaps, but also with approval of design details of winding equipment.

27 Further visits should be made to the largest coal producing organisation (Ruhrkohle) and the Inspectorate (CMA). It is felt that further detailed consideration should be given to the difference in winding engine control philosophy mentioned in paragraph 11 of this section.
APPENDIX 38.1 Visit to Germany: mechanical aspects to be discussed

1 Continental regulations, standards and test criteria eg Are design criteria for winding engines codified on the lines of DIN 22403? What standards do the German Inspectorate or others require, and what methods and frequency are adopted for non-destructive testing of mechanical and structural parts of winding equipment?

2 What materials are used in Germany for the construction of mechanical and structural parts of winding equipment such as winding engine components, cage hangers, attachments of suspension devices to cages and disc brakes?

3 Possible experimental work at the Tremonia Experimental Mine, eg stress measurements on winding engine components, establishment of design data for winding engines, deceleration rates and energy absorbing devices.

4 How are materials for Koepe sheave and brake linings tested and assessed? Are dynamic tests carried out on winding engines or are they merely laboratory tests?

5 Control or warning devices: for example, are facilities provided in Germany for measurement of brake torque reaction, or retardation, or for detection of lack of retardation? Testing procedures for control or warning devices.

6 Is there any formalised system in Germany for assessing safety and reliability of winding installation considered as a whole eg is the reliability of each component considered in the light of influence of other components on it and its influence on control of the winding system?

7 What maintenance procedures and documentation are employed in Germany; and are there facilities for accumulation of failure reports such as facilities for compiling a data bank of problems and troubles?

8 What is the maintenance organisation? How are schemes of maintenance administered? Are staff qualified engineers or clerks?

9 Is it considered that the standard of maintenance achieved in Germany is high? If so, to what is this attributed?

10 Is difficulty experienced in making time available for maintenance of equipment?

APPENDIX 38.2 Translation of appendix 3 to German Man Winding Regulations of 1st August 1957

Instructions concerning applications for certificates granting permission for erection and operation of main man winding installations

Applications for permissions to erect and operate main man winding installation in accordance with section 2 of Man Winding Regulations shall be addressed to the Chief Mining Inspectorate and submitted, in duplicate, to the appropriate Local Mining Inspectorate. One copy will be returned to the applicant; the other will remain with the mining authorities.

The statements of specifications for the equipment of main man winding installations (see appendix 3a) of specifications for ropes to be used therein (see appendix 3b) and the works certificates for the winding engine (see appendix 7) and for the rope sheaves (see appendix 6) together with drawings, specifications and dimensions, are
to be appended to the applications, as directed by the following schedule. All data shall be compiled in the appropriate manner. In addition, two loose extra copies of statements of specifications as shown in appendix 3a and b shall be submitted with the applications. One of these is required for the use of Chief Mining Inspectorate, the other for the rope testing station.

In the case of applications for permission to make alterations in man winding installations in accordance with section 4 of Man Winding Regulations, only data concerning the specific alterations proposed shall be appended; where alterations occur in many figures in the statements of specifications on this account, the statements shall be submitted with all figures filled in and the altered figures underlined in red.

1 Drawings, specifications

Plan of site

For surfacing shafts, a plan showing the layout of the shaft and of the surrounding buildings on the surface. For staple shafts, a section from the ground plan showing the position and ventilating system of the staple shaft and of the winding engineroom.

Ground plan of the man winding equipment

The situation of the winding engine in relation to the shaft including shaft equipment: scale 1:100.

Vertical section of the man winding equipment at the surface (At the end of the staple shaft)

The pit headframe with rope sheaves and deflection sheaves (rope sheave frame in the staple shaft) and the fleet angles of the ropes, and showing:

- the position of the buffer beams and catch props
- the position of the top landing, with man winding platforms
- the position of the thickened guide timbers
- the position of the terminal switch

including also a drawing of the cage (skip, counterweight) together with the suspension gear.

(1) in the highest operational position at the top landing

(2) under the buffer beams

showing the free height for man winding and overwind space for material winding; the free drop and the passage way for suspension gear through the buffer beams: scale 1:100.

In cases where the free height and overwind space for material winding are not identical, it is recommended that an additional simple diagram of the respective heights be appended, apart from the actual vertical section for the various stages of operations.
Vertical section of the man winding equipment at the lowest landing and below

Showing:
- the position of the landing and man winding enlargement
- the position of the thickened or converging guide timbers
- the position of the support bracing of the guide timbers
- the position of the tail rope loop, including tail rope guides
- the position of the bottom of the shaft at the staging

including also a picture of the lowest operational position of the cage (skip, counterweight) together with the suspension gear at the landing: scale 1:100.

Dimensions of the shaft (Cross section of the shaft)

Scale 1:50.

For air shafts, if applicable, shaft covers: scale 1:20.

Buffer beams, including support bracing of guide timbers

Scale 1:20.

Ground plan and vertical section of the winding engine

Including brakes: scale 1:10 or 1:20.

For electric winding engines, an additional wiring diagram (effective power wiring diagram and diagram of the current path of the safety circuit) including a short explanation of the mode of operation.

Suspension gear

Scale 1:10.

The cage (skip, counterweight)

Scale 1:10.

The tail rope suspension mechanism

Scale 1:20.

The wiring diagram and specifications

The electrical signalling and telephone installation including a list of components.

The wiring diagram and specifications

Any other electrical controlling mechanisms or communication equipment (eg flush decking indicators) including a list of components.


**Shaft gates**

A diagram of their mode of operation, as a wiring diagram with a short explanation, including a list of electrical components.

**For electrical installations in staple shafts apart from communications equipment**

A plan of the workings or map of the site showing the location of the component structures as well as cables and small wiring.

Short circuit system.

**APPENDIX 38.3 Materials used for mechanical parts of brakes**

1 The information contained under the first two headings below is the recommendations obtained from WBK on the selection of materials for mechanical parts of brakes.

**Bolts, pins and rods**

Steels to DIN 17200 grades Ck 35 and Ck 45. These are medium carbon steels hardened and tempered in the tensile range 60 to 70 kp/mm². The symbol k in the grade indicates low sulphur and phosphorus contents 0.035 maximum.

**Shoes and fabrications**

Welding quality steel to DIN 17100 grades R St 37 – 2, and R St 42 – 2. The steels are fully killed or balanced and possess guaranteed notch ductility at +20°. St 52 – 3 is used in special circumstances and is fully killed possessing guaranteed notch ductility at –20°. At Tremorion Experimental Mine, it was stated that the brake disc was made from St – 50 steel segments bolted to the main drum. It was not known which variety of St – 50 was used.

**Materials used in main safety brake**

4 In the SSW single action rapid action brake type JM 541 the following materials are used:

**List 12** See fig 1 of this appendix

- Pressure rod 1 St 42.11
- Pins St 60.11
- Main brake lever 2 St 37.21
- Small brake lever 3 St 37.21
- Brake shaft 4 St 50.11
- Brake rod 5 St 42.11
- Brake post 6 St 37.12

**List 15** See fig 2 of this appendix

- Pins 1, 3,5 and 9 St 60 – 2
- Brake shafts 2, 4 St 50 - 2N
- Pull rod 10 M St 42 – 2
- Pull rod ends St 50 – 2
- Pull rod nut MU St 34
- Anchor bolt 11 St 50 – 2
Lever 6 M St 42 – 2  
Foundation bolt 13 40  
Lever 7 M St 52 – 3  
Pressure rod 12 M R St 37 – 2  
Brake weight rod St 50 – 2

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**Figure 1** To illustrate list 12

**Figure 2** To illustrate list 15
List 21 See fig 3 of this appendix

Main brake lever 1
St 34 – 2
Connecting rod 2
St 34 – 2
Fork ends at J and L
St 42 – 2
Pins at M, J and L
St 42 K
Pins in brake piston
St 50 K
Piston rod 3 in connecting cylinder
X10 C13

5 It will be noted that the materials used in this brake (designed in 1966) do not fully agree with those recommended by WBK. However, materials with guaranteed notch ductility have been used for each critical components as pull rods and main brake levers.

Materials used by GHH

6 Discussions with GHH revealed the following information about selection of materials, manufacturing processes and testing during manufacture.

7 The brake paths used by GHH are of steel plate for both disc and shoe brakes. The steel used is St 52 – 3 and the whole construction is normalised and stress relieved. They accept that grey cast iron is probably the best material for brake paths but they do not like cast components because these did not fit into their method of all welded drum construction. They stress relieve all welded components at 630°C after welding, but not components manufactured in situ, and for this reason they prefer to complete welding of all components at the factory. J-preparation welds are used on drums and to date there have been no failures. Shafts are made from low carbon steel forgings in C35 k but also in C22 and sometimes St 52. These are forged at the GHH works and every forging has a forged on test piece. Rods are made from C35 or C45 forged. The forgings are ultrasonically tested before machining. For important items which are subject to complex stress St 37 – 3 is used. Any plate is first ultrasonically tested.

8 During manufacture forgings are ultrasonically tested, chemically analysed, and mechanically tested for tensile strength and notch ductility.
APPENDIX 38.4 Translation of 1975 working programme at WBK rope testing station (Seilprüfstelle)

Working programme (short version) as at 1975

1 The activities of the institute concern three duties: monitoring, training and research. These subjects cover the entire range of main shaft winding including headframes, winding ropes, shaft guides, winding engines and electrical installations, and the entire mechanical parts of staple shaft winding systems underground as well as rail haulage installations either rope hauled or self contained.

2 The Seilprüfstelle (Official Winding Rope Testing Station) is responsible in the Ruhr coal mining industry for acceptance tests of new winding engines, governors and other safety installations, and their signalling mechanisms as well as their regular monitoring. All applications filed in the Ruhr with the mines inspectorates for approval and/or modification of manriding in main shafts are first checked by the testing station. The mines inspectorates ask the testing station to participate in the drawing up of new rules and regulations about manriding in shafts, and haulage roads as well as in the investigation of accidents.

3 The testing station collects all experience gained by the Ruhr collieries in the field of shaft winding. That is why the collieries make wide use of the expert advice of members of the testing station when planning new mining plants or when investigating operational difficulties, defects in operation and accidents.

4 In the field of wire ropes, the manifold influences of material, and the properties of the wires, as well as of the type of stranding, on the behaviour during use, and the working lives of the ropes, have been studied for a long time by research work and investigation. The station is provided with numerous testing machines, and fully equipped with metallographic and chemical laboratories, as well as a plant for the analysis of material by the x-ray fluorescent process, and is available for this purpose. Moreover, statistics are kept and analysed for discarded winding ropes for the area of the Federal Republic of Germany (except Saarland).

5 The saving in cost of purchasing winding ropes, owing to extension of operating lives at mines, amounts to about 12 million DM during one year.

6 The station owns a large number of testing machines with maximum forces up to 1200 MPa for static tests and loads up to 250 MPa for pulsating tests. For the testing of wire ropes, clamping spans up to 25 m are available. The testing machines can be used universally: meaning that all the usual strength and fatigue tests and the determination of toughness and elongation measurements can be made with steels as well as with any building material. Some testing machines, however, are designed for the special needs of rope and chain testing. Thus, several testing machines for combined fatigue strength tests under pulsating tensile and reverse bending stresses were developed during recent years, on which winding ropes of any sizes and splicing connections can be investigated.

7 Special testing installations exist for friction and wear tests on driving sheave and brake linings. Fibre ropes, safety belts, swivels and protecting nets can be tested by means of drop tests.

8 The station makes use of several ultrasonic devices for non-destructive testing of materials. A flameproof ultrasonic device is available for measurements of the wall thickness in pipelines and containers used in coal mines. Investigations of cracks and flaws can be realised by the usual magnetic and dye-penetrant methods as well as by instruments measuring the depths of cracks and flaws.
9 A magnetic inductive testing method was developed in order to detect interior damage to winding ropes. These devices, of a flameproof type, can also be used underground in coal mines. Besides, special measuring instruments, also of a flameproof type, have been designed to determine the tensile forces in wire ropes whilst in operation.

10 In order to check the operating conditions for winding ropes, the testing station has instruments to measure the condition of shaft guides and the velocity and acceleration of conveyances and winding engines. Other instruments, developed by members of the institute, are available for measurements of forces acting between conveyances and shaft guides.

11 On a testing area for rope hauled trains, the manifold influences on working life of haulage ropes and their joints are investigated. An incline with variable gradient enables functional tests on brakes and carriages of such haulages to be carried out. Instruments have been developed for measuring forces in haulage ropes and track, and for the speeds of cars in order to monitor haulage installations underground whilst in operation.

12 Frequently, acceptance tests are carried out in the works of manufacturers on wire ropes for cable ways and other purposes. The Seilprüfstelle has been appointed an official testing station for such duties by the authorities concerned. Besides, the station is often asked to give advice in matters concerning winding or haulage ropes; and to investigate accidents outside the mining industry, eg on ropes used for cranes, ships etc. The Seilprüfstelle has also been admitted as an official acceptance testing station by the API (American Petroleum Institute).

13 As for investigations of conveyor and coal plough chains and chain sprockets, the station makes use of various modern testing machines for load tests on stationary and moving chains as well as for the detection of cracks and flaws. Engineers of the station also carry out acceptance tests in the works of chain manufacturers.

14 The testing station participates activity in numerous standardisation committees and international associations in the field of winding ropes, shaft winding and haulage. There is an intensive exchange of opinions and experience with many institutes and departments in Germany and abroad. Often, the station is asked by companies, institutes and organisations, in other countries, to give advice on planning work and to investigate shaft winding installations.

15 The station makes an essential contribution to the prevention of accidents. Knowledge obtained by research and development work is published in papers and communicated in lectures to engineers and officials of mining companies and collieries. These persons are also regularly instructed about proper care and monitoring of shaft winding and haulage installations.

16 By order of the mines inspectorates, all winding enginemen of the Ruhr coal mining industry must be theoretically trained by the testing station prior to their appointment as trained winding enginemen, they have to undergo an examination by an expert of the station.

17 Haulage rope splicers are also examined by an expert of the institute at regular intervals.

18 Each year, about 3000 technical reports are produced and 500 applications and additional applications are examined for approval in respect of shaft winding installations. About 1500 other examination tests and acceptance tests of
equipment whilst in operation are carried out. About 4000 tests are annually run in the station laboratories and workshops.

APPENDIX 38.5 Summary of facilities, and scope of work done, at WBK rope testing station (Seilprüfstelle)

1 Investigations to assess the performance of winding and other ropes form a major part of the work at Bochum. The institute has numerous testing machines with maximum forces up to 1200 Mp for static tests and loads up to 250 Mp for pulsating tests. Some purpose designed machines are used for combined fatigue strength testing of ropes under pulsating stress and reverse bending.

2 Testing facilities for rope haulage systems include a test incline with variable gradient on which cars and car brakes are tested. Equipment is also available for approval testing of friction winding engine tread and brake lining materials.

3 The scope of research and investigatory work carried out may be summarised briefly as follows:

- tensile tests and strength recording on steel wire ropes;
- fatigue tests on steel wire ropes;
- tensile tests on natural and synthetic fibre ropes;
- individual wire tests;
- drop tests on fibre ropes, life lines and safety belts;
- general mechanical testing;
- tests of mine support materials and conveyance guide timbers;
- metallographic examination and chemical tests of steel;
- ultrasonic and magnetic particle tests of metals and components.

4 The institute is also involved in routine examinations of operational equipment and in special investigation work which includes:

- winding rope examinations using electro-magnetic testing;
- examination of suspension gear;
- shaft inspection including measurement of guide reaction forces;
- winding engine inspections including speed controllers and braking equipment.
APPENDIX 38.6 Summary of facilities, and scope of work done, at Tremonia Experimental Mine, Dortmund

1 Tremonia is a closed mine which is now used for experimental purposes. Work on winding systems is mainly concerned with testing of rigid guide systems, ropes, suspension gear, winding engine brakes and brake friction materials. Investigations are presently being made into means of improving the examination and maintenance of flat balance ropes: non-destructive testing cannot yet be applied to these ropes and it is proposed to develop a shaft platform to provide safe access for examination.

2 The main shaft winding installation is a four rope tower mounted friction winding engine rated at 2000 kW and capable of hoisting a 20 tonne payload from 520 m. The friction drum is fitted with both brake discs and cylindrical brake paths so that different brake arrangements can be tested.

3 Considerable emphasis appears to be laid on establishing efficiency of winding engine brakes. Transducers have been developed to measure loads in tie rods and enable the efficiency of force transmission from brake engine to tie rods to be established, and to give also a ready check of load distribution between twin tie rods. A maximum variation of ten per cent between loads in twin tie rods is permitted.

4 No practical work has been done on brake torque reaction devices but such devices are apparently being considered.

5 Laboratory testing facilities include a dynamometer type rig for testing the coefficient of friction and fire resistant properties of brake linings. The brake lining is forced against a rotating drum and the debris is allowed to fall on fabric impregnated with potassium chlorate. The time to ignite the fabric under various ruling conditions is a measure of the flammability of the lining material. Tests have been carried out with brake linings contaminated with hydraulic fluid and it is claimed that contamination results only in a temporary reduction in the coefficient of friction. No tests have been made on linings contaminated by grease or lubricating oil.

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