DEPARTMENT OF ENERGY

ACCIDENT AT MARKHAM COLLIERY DERBYSHIRE

REPORT

On the cause of, and circumstances attending, the overwind which occurred at Markham Colliery, Derbyshire, on 30 July 1973

by

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Date: 6 March, 1974

The Right Honourable Eric Graham Varley, M.P.
Secretary of State for Energy

Sir,

In compliance with the direction given by the Right Honourable Peter Walker, M.B.E., M.P., Secretary of State for Trade and Industry, under Section 122 of the Mines and Quarries Act 1954, I held a Public Inquiry into the accident at Markham Colliery on 30 July, 1973, which caused the deaths of 18 men and in which another 11 sustained serious bodily injury. One other man was seriously injured during the rescue operations. I now have the honour to submit my report.

2. I opened the Inquiry at Chesterfield Town Hall on 10 October, 1973 and it lasted for six days during which time 55 persons gave evidence. Their names and occupations are given in Appendix I.

3. The interested parties were represented as follows:

The Department of Trade and Industry, Mr. D. Richards, H.M. Senior District Inspector of Mines and Quarries, Mr. L. D. Rhydderch, H.M. Deputy Chief Inspector of Mines and Quarries, Mr. S. Luxmore, H.M. Principal Electrical Inspector of Mines and Quarries, Mr. T. K. Clanzy, H.M. Principal Inspector of Mechanical Engineering in Mines and Quarries.

The National Union of Mineworkers, Mr. P. E. Heathfield, General Secretary, Derbyshire Area, Mr. A. Bulmer, Mining Engineer, Derbyshire Area, Mr. K. H. Saunders, Mining Engineer for the National Union of Mineworkers, Mr. F. Wilks, Regional Officer, No. 4 Region, Colliery Officials and Staffs Association.

The National Association of Colliery Overmen, Deputies and Shotfirers, Mr. K. Moore, Assistant General Secretary, Midland Area, Mr. S. Evans, General Secretary, Midland Area, Mr. F. Roddy, General Treasurer, Midland Area, Mr. C. B. Hopkin, Consultant Mining Engineer, Mr. A. Plummer, Consultant Mechanical Engineer.

The National Coal Board, Dr. H. L. Willett, Deputy Director-General (Mining), Mr. W. J. Currie, Director of Engineering, Mr. R. B. Dunn, Area Director, North Derbyshire Area, Mr. J. H. Northard, Deputy Director (Mining), North Derbyshire Area, Mr. J. N. L. Woodley, Deputy Director, Mining Research and Development Establishment.

The British Association of Colliery Management and The National Association of Colliery Managers Limited, Mr. J. W. Pirie, Technical Adviser, Mr. J. Rodgers, General Manager of Markham Colliery, Mr. G. E. Tyler, General Secretary, Mr. M. A. Fairnie, Regional Organising Secretary, East and West Midlands and North Western Region and Mr. G. L. Amott, Branch Chairman, North Derbyshire Branch, of the British Association of Colliery Management.

4. I find that the 18 men lost their lives and the other 11 sustained serious bodily injury because the cage in which they were travelling in the No. 3 shaft crashed into the pit bottom as a result of an overwind. There was a short delay in reaching the injured men because the cage gates were distorted but despite this the last casualty was brought to the surface just over two hours after the accident. I am satisfied that the evidence given at the Inquiry was sufficiently comprehensive to enable me to determine the cause and circumstances of the overwind. The names of the men who lost their lives and of the injured are given in Appendix II.

DESCRIPTION OF THE COLLIERY

General

5. Markham Colliery is one of 14 producing mines in the North Derbyshire Area of the National Coal Board and is situated near Duckmanton about five miles by road to the east of Chesterfield. At the time of the accident the saleable output was 30,000 tons per week with 1,870 men employed below ground and 425 on the surface.

6. There are four shafts (Plan No. 1 shows their location) arranged in pairs with No. 1 (downcast) and No. 4 (upcast) near the general offices and No. 2 (downcast) and No. 3 (upcast) some 350 yards to the south. Coal winding is confined to Nos. 1 and 2 while Nos. 3 and 4 are used for winding men and materials.

7. At the top of No. 3 shaft there is an Aerex radial flow fan which extracts 238,000 cubic feet of air per minute at 9·8 inches water gauge.

Management

8. The principal officials holding statutory appointments for Markham Colliery including the winding equipment at No. 3 shaft, were:

Area Director	R. B. Dunn
Deputy Director (Mining)	J. H. Northard
Area Chief Mining Engineer..	T. W. Peters
Area Chief Engineer	G. Godfrey
Colliery General Manager	J. Rodgers
Colliery Mechanical Engineer	W. Fox
Colliery Electrical Engineer	C. C. Levers

There were two Deputy Managers, each holding statutory responsibility as Undermanager for a part of the colliery. D. Hotchkiss, the Senior Deputy Manager, was responsible for the surface and No. 3 shaft.

9. Other officials whose responsibility included the winding equipment at No. 3 shaft were:

Area Mechanical Engineer	A. G. Harley
Area Electrical Engineer	M. Blythe
Colliery Chief Engineer	J. A. Plant

WINDING EQUIPMENT AT NO. 3 SHAFT

Shaft and headframe (Plan No. 2)

10. In 1886 No. 3 shaft was sunk to the Deep Soft seam at a depth of 1,626 feet. Subsequently, the lower 189 feet were filled in and the existing pit bottom established at 1,407 feet—the Ell Coal seam level. The shaft is 15 feet diameter and brick lined throughout.

11. There are two double-deck cages each capable of carrying a maximum of 16 persons per deck. Each cage is attached to a $1\frac{1}{8}$ inches diameter locked coil winding rope and guided through the shaft by four $1\frac{1}{2}$ inches diameter half locked coil ropes on the side nearest to the shaft wall. There are two rubbing ropes between the cages and these, together with the guide ropes, are suspended from white metal filled swivel glands in the headframe and tensioned by weights in the shaft sump. In the pit bottom the cages land on wooden baulks set into the shaft walls. On the north side a platform gives access to the top decks so that simultaneous loading or unloading of men can take place.

12. At the shaft top a circular brick tower forms an airlock and supports a steel frame for the detaching bells and the headgear which has back stays to ground level. Steel tie rods from the frame to the brick tower give additional stability. Access to an overwound cage suspended from the detaching bell is provided but there are no headframe catches to support a cage in that position. Either cage can ascend 15 feet 9 inches above the normal decking level before it is detached from the winding rope.

Winding engine

(i) General

13. Plan No. 3 shows a general view of the airlock, No. 3 winding engine house and the motor generator house. It also shows a detailed plan of the engine house and an enlarged view of the winding engineman's cabin.

14. The 440 horse power Ward Leonard winding engine was supplied by The British Thomson Houston Company Limited, Rugby, with mechanical parts designed and manufactured by Markham and Company Limited of Chesterfield. It was installed at Do Well Colliery, owned by the Staveley Coal and Iron Company Limited in 1921 and transferred to Markham No. 3 shaft about 1930. In 1945, the cylindrical drum was fitted with a centre ring and in 1949 a replacement automatic contrivance of the torque controller type was installed and commissioned by Tudor Auto Services Limited, now Blacks Equipment Limited. In 1952 the original deadweight brake was replaced by the

servo-spring brake unit in use at the time of the accident. This was manufactured by S. Briggs and Company Limited and installed by Tudor Auto Services Limited. At the same time a Lockheed hydraulic impulse brake tripping system was installed but this was replaced in 1960 by a Blacks high pressure oil tripping system. In the same year, the 30 hertz (cycles per second) alternating current apparatus was converted to operate from a 50 hertz power supply. In 1961 the number of men permitted to travel in each cage was increased from 24 to 32. Thicker barrel plates and a new centre ring were fitted to the drum in 1963 and the cast iron brake shoes and fulcrum brackets were replaced by mild steel parts in the following year.

15. The engine is used only to wind men, materials and limited quantities of stone and as this duty does not require a predetermined winding cycle for production purposes it is left to the enginemen to regulate the speed and the rates of acceleration.

16. The ropes are attached to the drum by means of white metal sword capels bolted to the drum sides adjacent to the brake paths and when fully wound on are double layered. A new rope has about 11 'dead' coils to allow for recapping.

17. The drum is connected by a solid coupling to a direct current motor (winder motor) which has separately excited field windings and an open loop control system. The armature is supplied by the generator of a Ward Leonard motor generator set driven by an alternating current slip-ring induction motor housed with its associated control equipment in a separate building adjacent to the winding engine house.

18. The speed and direction of rotation of the winder motor are controlled by movement of the engineman's control lever within a quadrant which has a middle 'off' position. Forward or backward movement of this lever operates electrical contacts which determine the polarity of the generator field and thus the direction of rotation of the winder motor (Plan No. 4). The lever also operates a rheostat which varies the generator field strength and hence the output voltage of the generator. Except at low speeds the winder motor speed is proportional to voltage for a particular load but for each change in load this proportionality alters.

19. One of the winding enginemen describing a normal wind with an equal number of men in each cage said that after receiving the necessary signals he moves the control lever in the appropriate direction from the 'off' position gradually applying power to the winder motor and slowly releasing the mechanical brake. The voltage applied to the motor is then progressively increased to accelerate the winding drum until the indicated voltage reaches 300 to 320, which gives a drum speed of about 40 revolutions per minute and a rope speed of about 20 feet per second (13.6 miles per hour). This speed is maintained until the position of the cages in the shaft corresponds to about 10 drum revolutions (283 feet) from the end of the wind when the generator voltage is gradually reduced by moving the control lever towards the 'off' position to increase regenerative braking. This braking is available to reduce speed during a wind and, if there is a descending out-of-balance load, to maintain a selected speed.

20. During regenerative braking the winder motor, which is then being driven by the load, becomes a generator with an output voltage higher than that of the Ward Leonard generator. This causes the generator to drive the alternating current motor which in turn becomes an induction generator feeding power back into the colliery supply system thus producing a braking effect on the winding engine. The engineman maintains this braking as the wind continues by progressively reducing the voltage to about 200 at 6½ drum revolutions (184 feet) from the end of the wind, when a warning bell rings. He continues to decrease the voltage and, consequently, the speed of the cages by gradually bringing the control lever to the 'off' position. At about four revolutions (113 feet) from the end of the wind he progressively applies the mechanical brake until the cages come to rest. With a heavy out-of-balance load descending the engine is controlled in a similar manner but the mechanical brake is applied earlier.

21. The enginemen estimate the loads in the cages from readings of winder motor current on a centre zero ammeter connected in the main direct current loop (Plan No. 4). When loads in the two cages are similar the starting current is about 800 amperes and this reduces to zero as the cages approach the mid-point of the shaft. As the weight of the descending rope becomes predominant the motor current automatically reverses to produce regenerative braking, the value of braking current being indicated on the opposite side of the ammeter scale. With a maximum out-of-balance load descending the starting current is lower, regenerative braking develops earlier and the magnitude of braking current is greater than that obtained with equal loads in the cages.

22. Although regenerative braking provides an efficient means of reducing the speed of a Ward Leonard winding engine it is only available on the No. 3 winding engine when the electrical systems are operating normally. There is no regenerative braking if the power supply fails, if any of the safety devices operate or if the emergency stop button is pressed.

(*ii*) *Mechanical brake*

23. At the time of the accident a Burns Cradle type brake was in use (Plan No. 5). It consisted of a pair of Ferodo lined brake shoes applied to the underside of the brake paths by the action of the compressed spring nest operating through a system of levers. The brake was released by using compressed air to counteract the force of the spring nest and move the brake shoes away from the drum brake path. During normal braking the winding engineman's brake lever operated an Iversen type valve which controlled the flow of compressed air to a servo-cylinder.

24. The force from the spring nest was transmitted to the main lever of the brake system by a 2 inches diameter steel rod 8 feet 11¾ inches long, located in the centre of the nest, constrained by a plate at the top and connected by a cross-head trunnion to the main lever at the bottom. The piston of the servo-cylinder was connected to the free end of the main lever and when compressed air was admitted to the cylinder this lever was forced down and the brake released.

25. If the power supply failed or any of the safety devices operated, or if the emergency stop button was pressed, the emergency brake solenoid was

de-energised and the 'ungabbing' gear immediately disengaged the engineman's brake control lever from the Iversen type valve and caused the mechanical brake to be applied (Plan No. 5). The 'ungabbing' gear could not be reset until the brake control lever was returned to the 'brakes on' position and the safety circuits were energised.

(iii) Safety equipment

26. The automatic contrivance was a Blacks controller driven from the drum shaft through a system of gears which also drove a vertical pillar type depth indicator showing the position of the cages in the shaft. It was designed to cut off the power supply to the winder motor and cause the mechanical brake to be applied to prevent the cages:

(*a*) reaching an excessive speed in the acceleration, constant speed or retardation zones;

(*b*) being landed on the baulks at a speed exceeding five feet per second; and

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

The controller had a centrifugal governor, dial mounted cams and overspeed and overwind switches which operated in conjunction with back-out switches and two electrical safety circuits.

27. One of these circuits, which included the brake solenoid and all the protective features provided by the automatic contrivance, was interlocked with the other—the pilot safety circuit—which has two contactors in parallel. These contactors can be tripped by various safety devices including the winding engineman's emergency stop button, an overwind switch on the depth indicator, the Ward Leonard overcurrent relay and the slack rope and brake wear switches. The pilot safety contactors have contacts in series with two parallel connected main safety contactors which control the supply of electricity to the winder motor and the brake solenoid. The schematic diagrams (Plan No. 4) show that the brake solenoid, pilot safety circuit contactors and the main safety contactors must all be energised to run the winding engine and, therefore, operation of any safety device should cut off the power supply and apply the mechanical brake. Visual indicators in the engineman's cabin show correct or incorrect operation of the pilot and main safety contactors.

28. Before winding men the engineman operated a lever which, through a linkage, altered the position of one of the cams on the automatic contrivance to enforce lower winding speeds. A switch on the lever gave visual indication to the banksman, onsetter and winding engineman that the lever was set for 'man winding' but did not positively prove the position of the cam on the automatic contrivance.

29. A rope speed indicator was installed in the engineman's cabin adjacent to the ammeter about 13 years ago but the associated tacho-generator was not fitted and the indicator never operated. Further technical details of the winding equipment are given in Appendix III.

THE OVERWIND

30. At about 5.35 a.m. on Monday, 30 July 1973 the dayshift winding engineman, R. W. Kennan, arrived at No. 3 winding engine house as the last of the nightshift men were being wound to the surface. Some 20 minutes later Kennan operated the winding engine to wind the first dayshift men into the mine and by about 6.20 a.m. 105 persons had been lowered.

31. The overlap rope cage (Bolsover side) was then loaded at the surface with 15 men on the top deck and 14 on the bottom deck. The underlap rope cage (Roadway side) was empty. The wind proceeded normally until the cages had passed the mid point in the shaft when Kennan began to retard the engine and, out of the corner of his eye, saw 'some sparks under the brake cylinder' and heard a bang. He immediately moved the control lever towards the 'off' position to increase regenerative braking and simultaneously pulled the brake lever towards the 'on' position. Operation of the brake lever felt 'the same as picking up a pen' and had no effect on the speed of the winding engine drum. Kennan continued moving the control lever towards the 'off' position but it appeared to him that this had little effect on the drum speed so he pressed the emergency stop button. He expected to see the drum 'brought to a sudden stop' but nothing happened and, as a last resort, he switched off the motor for the hydraulic pump which supplied the 'ungabbing' gear. This had no effect on the winding engine and the next thing Kennan remembered was bricks falling around him.

32. The ascending cage was detached from the underlap rope by the operation of the detaching hook in the headframe bell but continued to ascend until it struck the roof girders of the airlock structure where it fractured the surrounding concrete and brickwork. As there were no safety catches in the headframe the cage then dropped back until it was hanging by its suspension chains from the detaching hook.

33. The descending cage carrying the men crashed into the pit bottom with such force that it fractured nine of the 17 wooden landing baulks. Although power had been cut off before the crash, the momentum of the winding system unwound the spare coils of overlap rope and then the sword capel, with part of the drum side and brake path, was torn away. The rope and capel were pulled over the headgear pulley and then fell down the shaft on top of and alongside the cage containing the men. The drum continued to rotate and the flailing capel of the underlap rope seriously damaged the winding engine house and an adjoining workshop (Plate 1).

THE RECOVERY

34. It was immediately obvious to the men in the pit bottom that a serious accident had occurred and the onsetter entered his cabin to telephone to the surface while the winding rope was still falling down the shaft. He was unable to obtain an answer to his emergency call on the automatic telephone but spoke to the surface operator on a magneto telephone. The mine emergency organisation was brought into operation with a control centre at the surface.

35. On the north side of the pit bottom some of the tangled winding rope had to be moved aside and there was difficulty in opening the cage gates because their vertical slide rods had been distorted by the crash. Nevertheless, once the gates were opened the removal of casualties proceeded quickly. Injections of morphia were given to the very seriously injured as they lay in the pit bottom before being transported to the surface. Some were brought out through the adjacent No. 2 shaft and to minimise delay others were carried down a steep drift to No. 4 shaft some 700 yards away. The last casualty arrived at the medical centre about two hours after the accident.

36. In the early stages of the recovery there was some delay in sending casualties to hospital but the situation improved when additional ambulances arrived from the County Authority. The mobile emergency winding engine from Mansfield Rescue Station was in position alongside No. 3 shaft about 80 minutes after the accident.

37. J. Maxwell, who that morning had started work at Markham for the first time, was in the pit bottom at the time of the accident and was seriously injured when he fell from the top deck platform while assisting in the recovery.

THE INVESTIGATION

38. The circumstances of the accident indicated that there had been a complete failure of the winding engine brake and it was found that the centre rod in the spring nest had broken. A short length of this rod and the distance piece were found underneath the brake engine. It was agreed at the colliery that a small group of H.M. Inspectors of Mines and Quarries and National Coal Board Engineers should conduct the investigation and keep the interested parties informed of progress. Concurrent with this witnesses were interviewed.

39. The bottom deck of the cage which crashed on to the landing baulks was severely distorted but there was little damage to the top deck (Plate 2). Speed of impact was subsequently estimated to be 27 miles per hour. The top of the airlock was damaged and there was slight leakage of air but this did not seriously affect the ventilation of the mine. Inspection of the shaft from a hoppit wound by the mobile emergency winding engine revealed no serious damage and the shaft top was then sealed off to facilitate removal of the overwound cage and repairs to the airlock. Before investigation in the engine house could proceed the building had to be made safe and weatherproof.

40. The winding engineman's brake lever and the control lever were found in the 'off' position, the brake lever having moved to this position when released after the brake solenoid was de-energised. The 'ungabbing' gear had operated and the compressed air supply was still available at the Iversen type valve. The brake shoes were about $\frac{1}{8}$ inch clear of the brake paths, part of the drum side and brake path—where the overlap rope sword capel had been attached—was missing and the underlap rope was fully wound on to the drum with the capel lying in the drum pit. The column type depth indicator had overwound and one of the mounting brackets for the overwind screw on the automatic contrivance had broken due to overtravel of the traverse nut. The cross shaft between the engineman's brake lever and the Iversen type valve had been bent.

41. The man/coal lever and the associated cam on the automatic contrivance were in the 'man winding' position and this was indicated on the signal panel in the engine house.

42. In the motor generator house the 3,300 volts feeder switch had been isolated shortly after the accident occurred and the liquid starter and the circuit breaker for the motor generator set were seen to be in the 'off' position. All contactors and relays in the control cubicle were in their normal de-energised position. The exciter overcurrent, Ward Leonard overcurrent, and motor generator overspeed relays had not tripped. Although the circumstances of the accident did not suggest that it had resulted from, or was initiated by, a fault in any of the electrical systems these were carefully examined and tested. No defects were found which might have caused the accident.

43. The automatic contrivance was visually examined and when no defects were apparent in the mechanism it was sent to the manufacturer's works for thorough examination and test. When the cover was removed at the works it was found that the governor linkage had been displaced in transit because a grub screw in the reversing cam was loose. After this defect had been corrected it was established from the position of the traverse nut that the winding drum had overwound by $16\frac{2}{3}$ revolutions. The contrivance was then tested and the results obtained were similar to those previously recorded by the Area Overwind Testing Engineers.

44. At an early stage of the investigation the broken centre rod was removed from the spring nest and sent to the Safety in Mines Research Establishment for metallurgical examination. A replacement cross shaft and spring nest centre rod were fitted and the brake then operated correctly in response to the engineman's lever, and also when automatically applied. In a test it was demonstrated that the brake did not always fail safe, in that if the cross shaft lever keys or the pin in the lever above the 'ungabbing' gear were removed, the weight of the linkage opened the Iversen type valve and admitted compressed air to release the brake. Three nuts on the brake lever system were loose and these, with a number of keys, had not been made captive.

45. The centre rod appeared to have failed due to fatigue and, therefore, it was decided to investigate the loading and working conditions of a similar rod in service, consequently, the Director of the Safety in Mines Research Establishment was asked to arrange for a technical investigation of the spring nest assembly to be carried out. At the colliery four strain gauges were fitted at 90° to each other on the replacement centre rod as near as possible to the position where the fracture occurred in the original rod. With the winding engine drum stationary, the strains on the surface of the rod were measured with the brake off, when it was applied manually, then automatically and when power was applied to the drum with the brake on. The results of these tests showed that, in addition to the expected direct tensile stresses at the gauge positions, there were substantial stresses due to bending when the brake was operated. On the gauges at right angles to the winding drum shaft the magnitude of the stresses varied to such an extent that on the one furthest from the drum there was a change from tension to compression as the brake was released. Because the origin of these bending effects was not established the complete spring nest

assembly was sent to the Safety in Mines Research Establishment for further investigation (Plate 3).

46. In the laboratory the complete spring nest assembly was installed in a test rig and tests were made which accurately simulated operation of the brake. These confirmed that bending was the cause of the alternating stresses in the centre rod. Significant stresses were induced by bending in the lower part of the rod because the main lever was unable to rotate freely about the crosshead trunnion due to excessive friction between the trunnion axles and the bearing surfaces in the main lever (Fig. 1). It was found that if friction at the crosshead trunnion was relieved by forcibly separating the bearing surfaces and inserting lubricant the stresses in the rod caused by bending were significantly reduced. However, after a few operations the lubricant was forced out by the high bearing pressure.

47. Metallurgical examination of the spring nest rod showed that it had failed because of fatigue, where it passed through the distance piece, at a thread $4\frac{3}{4}$ inches from the bottom end (Fig. 2). There was evidence that three small cracks had existed for some time at this thread and that one of these had propagated to a depth of 1·1 inches before the rod broke (Plate 4). Numerous additional cracks existed in the threaded portion above and below the fracture (Fig. 3). Although small cracks, present in the region of the fracture, were found in the laboratory by the magnetic particle method of non-destructive testing, experiments showed that they would not have been revealed by applying an ultrasonic probe to the top end of the rod while it was installed in the spring nest. However, a saw cut representing a crack which had penetrated the rod to a depth of $\frac{3}{8}$ inch, was detected by an ultrasonic test.

48. All the main links and pins of the brake system were crack detected and minor defects were found, also worn and corroded bearing surfaces showed that lubrication had not been effective but it was concluded that none of these defects was significant to the accident.

49. The broken rod was made from 0·4 per cent carbon steel of good commercial quality with an ultimate tensile strength of 38 tonf/in^2 and the mean tensile stress induced by the spring nest at the minimum cross section was 6·2 tonf/in^2. Consequently, the static factor of safety was 6·1. However, because of bending, alternating stresses with an amplitude of $\pm$6·6 tonf/in^2 were superimposed on the tensile stress. This is far in excess of an appropriate working value of $\pm$3·6 tonf/in^2 for this type of threaded rod as quoted by Dr. Heywood in his book *Designing Against Fatigue*. On this basis failure of the rod was inevitable.

50. The results of the Safety in Mines Research Establishment investigation are contained in five comprehensive reports (Appendix IV) which were submitted to the Inquiry and will be published in their 'Technical Paper' series.

51. The manager's scheme for the systematic examination and testing of mechanical apparatus was comprehensive except that no provision had been made for non-destructive testing of the centre rod in the spring nest. The only record of a special inspection of this rod during its life of 21 years was an entry dated 19 February 1961, referring to a visual examination made by the

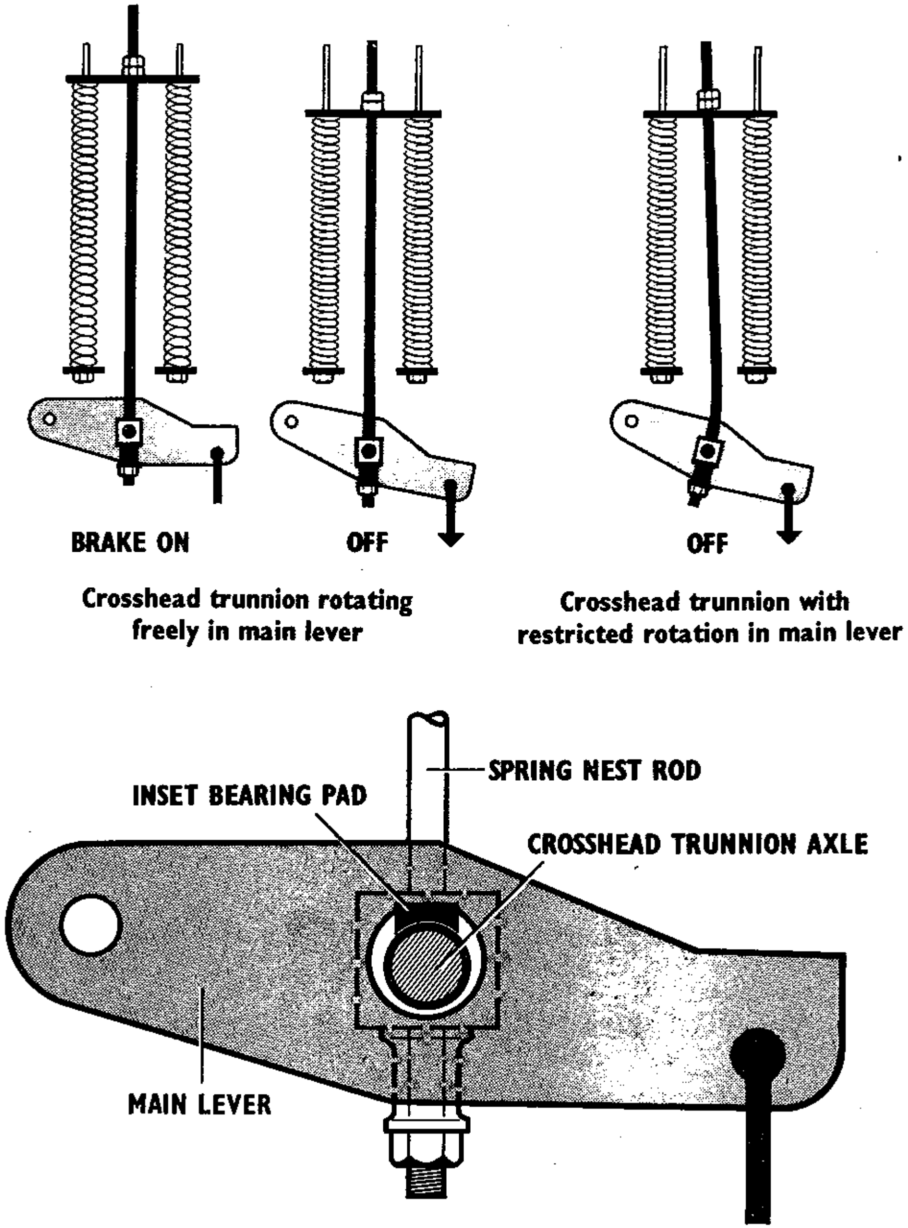

FIG 1
Spring nest centre rod: illustration of bending forces applied.

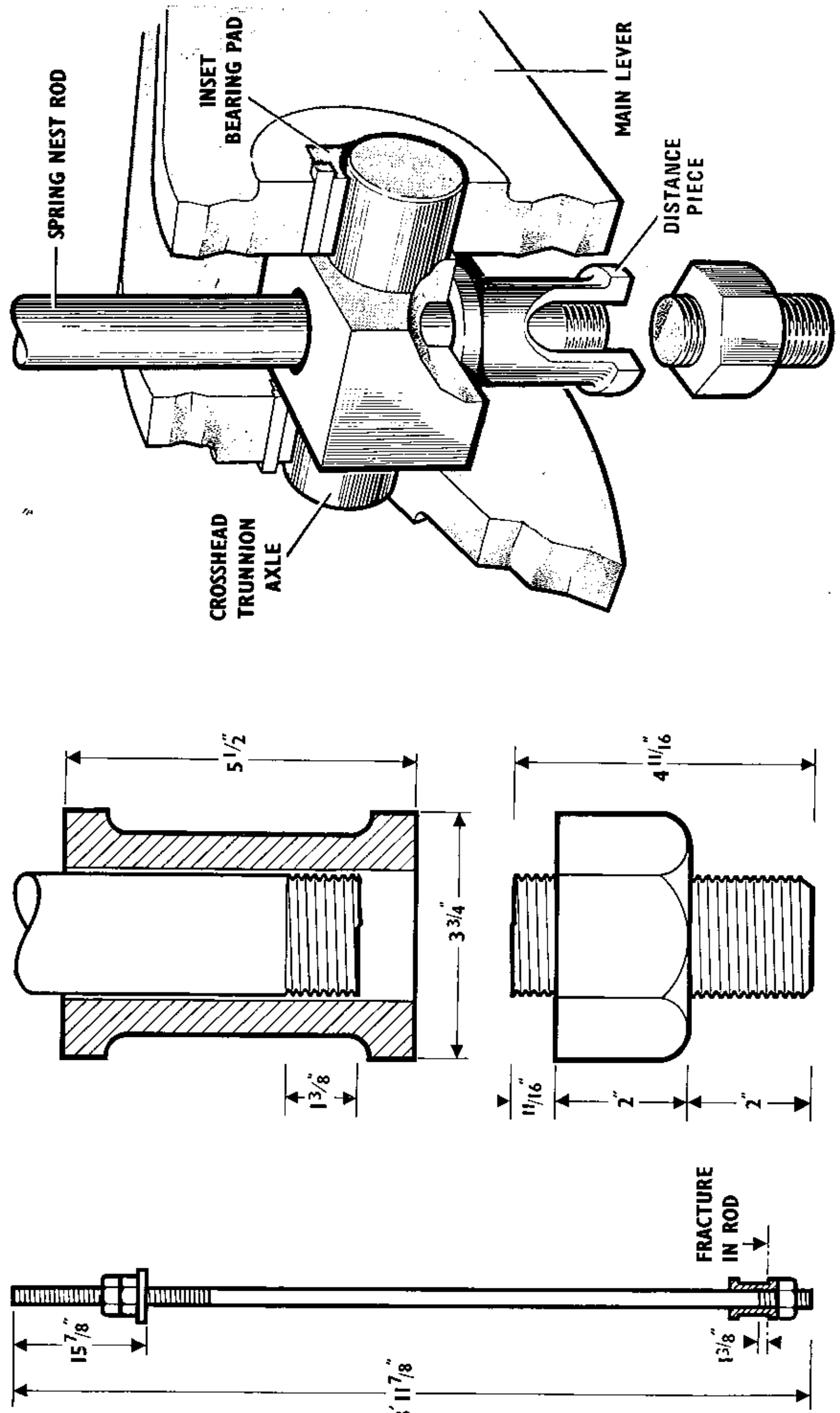

FIG 2
Spring nest centre rod and trunnion detail.

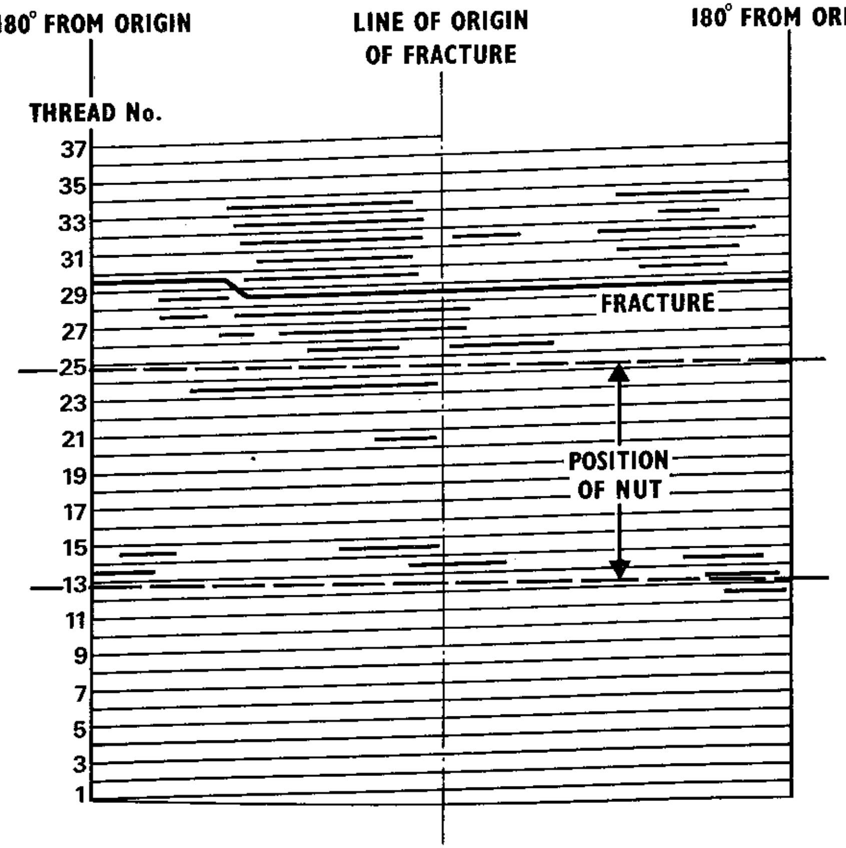

FIG 3
Cracks adjacent to fracture.

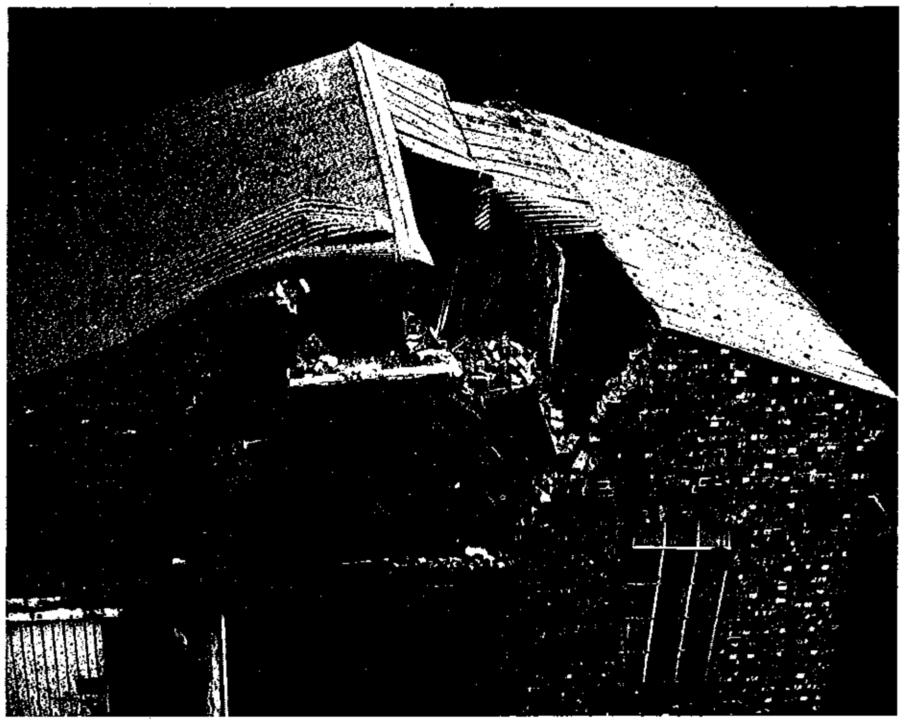

PLATE I
Winding engine house damage.

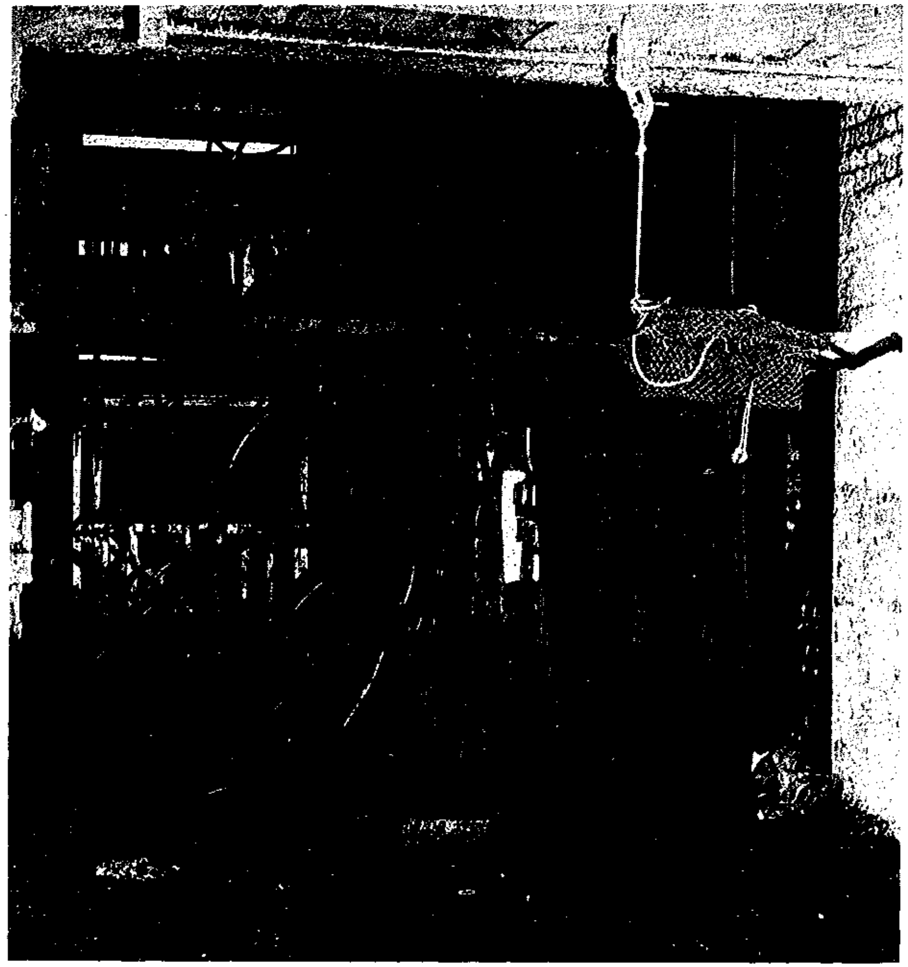

PLATE II
Damaged cage in pit bottom.

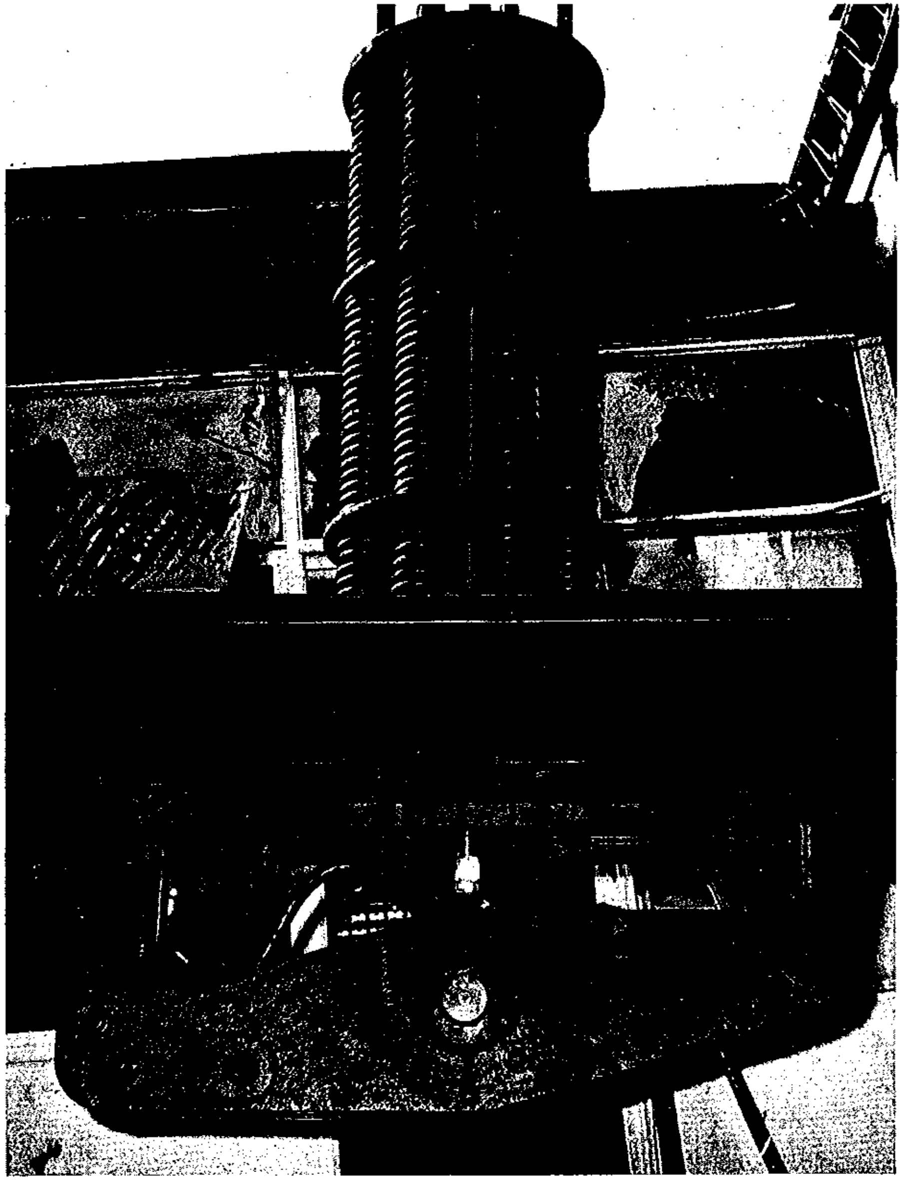

PLATE III
Brake engine after removal.

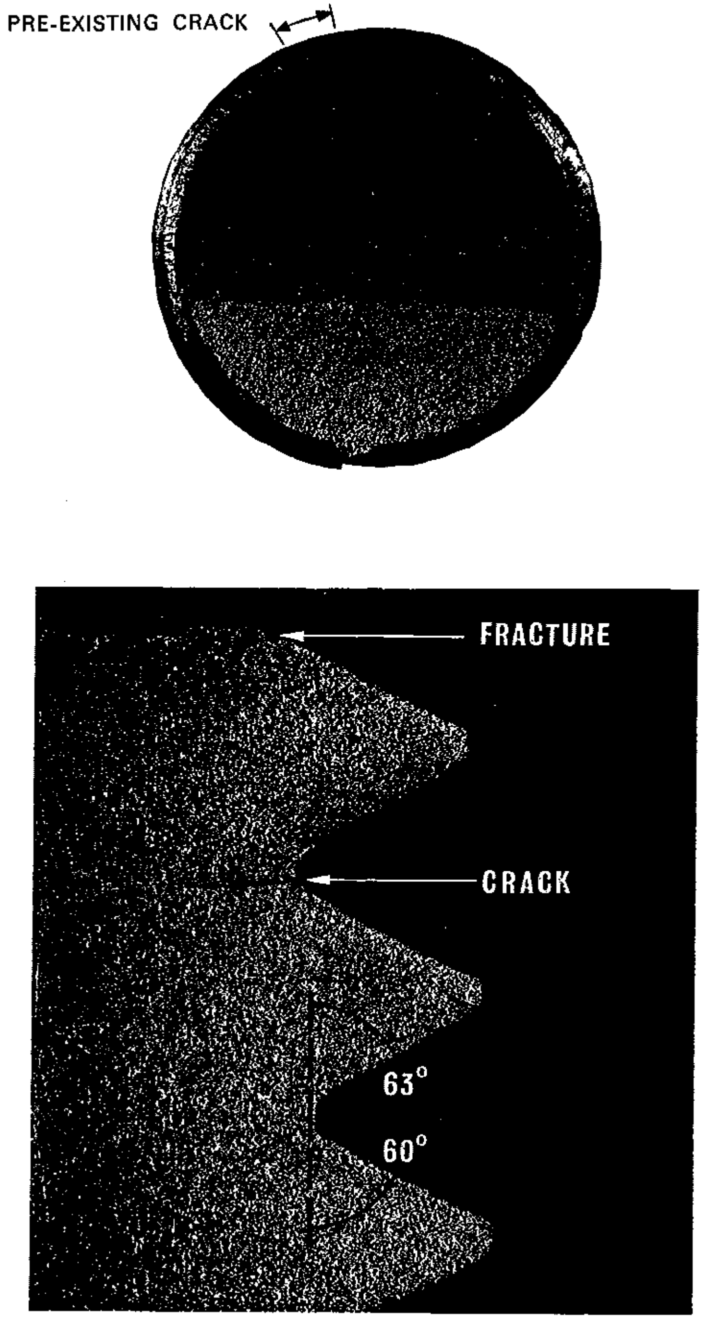

PLATE IV
Characteristics of fracture and thread form.
(Magnification factor of illustrations:
Top - X 1.15, bottom - X 7.00).

Colliery Mechanical Engineer in post at that time. This stated 'Examined brake rod in No. 3 Winder. Main Rod on Blacks servo unit nest of springs examined. Mr. Farnsworth'.

RECOMMISSIONING OF THE WINDING ENGINE

52. After completion of the investigation the winding engine was re-assembled with new spring applied caliper type brakes and a high pressure hydraulic system having duplicate brake solenoids, all supplied by Blacks Equipment Limited. The drum sides were replaced, barrel plates renewed, and a tacho-generator installed to operate the rope speed indicator. A reconditioned automatic contrivance was installed with an independent drive. Commissioning tests were carried out for the previous winding duties and, in addition, it was demonstrated that the winding system could be brought safely to rest by braking on only one brake path. The representatives of the interested parties agreed that normal winding could be resumed on 1 October 1973.

COMMENTS

53. It is necessary to comment on several matters considered at the Inquiry which are important for safe winding and although some of these are not relevant to the accident I consider that they warrant attention.

'Single line' components

54. The centre rod in the spring nest is an example of a 'single line' component as the safety of the men in the cage was completely dependent upon it. Such components should either be eliminated or so designed as to prevent danger, for example, failure of any 'single line' component in a braking system should cause the winding system to be brought safely to rest. Overspeed and overwind protection should not rely on single components, but where this is not possible they should be reliable and monitored to give warning of failure, or, alternatively, they should fail safe. All winding engines which are dependent upon only one brake path should be modified as should those where automatic application of the brakes is dependent on a single solenoid. Furthermore, there should be indication of any electrical fault in a safety circuit which could render it ineffective or, alternatively, the winding engine should be automatically brought to rest if a fault occurs in a safety circuit which would give rise to danger.

Maintenance and tests

55. A similar rod in a brake spring nest at Ollerton Colliery broke on 14 January 1961 and it was stated by P. Wood, Head of Shafts and Winding Section for the National Coal Board, that tests on this rod showed that stresses induced by bending were the cause of failure. Following this incident the Divisional Chief Engineer, National Coal Board, issued an instruction that the centre rod in all Briggs spring nests should be examined. This instruction did not give any guidance as to the nature and frequency of examinations required or to the use of non-destructive tests. Records showed that an external examination of the Markham rod was made on 19 February 1961, but probably because of lack of guidance, it appears that the rod was not removed for complete

examination at that time or subjected to non-destructive testing at any time during its life.

56. Laboratory tests on the Markham rod by the magnetic particle method revealed cracks of various dimensions in thread roots on each side of the fracture. Ultrasonic tests, which can be carried out *in situ*, did not detect these cracks but could have detected one $\frac{3}{8}$ inch or more in depth. The probability of detecting the crack which led to failure by the ultrasonic method would, therefore, have depended on its rate of propagation and the interval between tests.

57. The winding engine was tested by the Area Overwind Testing Engineers every three months and was stated by G. Godfrey, Area Chief Engineer, to have complied with all the statutory requirements. The National Coal Board draft memorandum entitled 'Testing the Safety Equipment on Drum Winders' prescribes the manner of testing and draws attention to the commissioning tests, which should be used for reference purposes. These were not available to the Area Overwind Testing Engineers. The loads used for testing were only estimated, and, on occasions, were greater than the equivalent man load. On other occasions no load was used. There was disagreement at the Inquiry between the testing engineers and the winding enginemen regarding the maximum torque applied to the drum during the statutory brake holding tests. Although I am satisfied that the way in which the tests were carried out had no bearing on the accident I consider that the requirements of the Testing Memorandum, which has been in process of development over 15 years, should now be made mandatory. The commissioning test records should be displayed in the engine house so that the results of all statutory tests can be compared. Area Overwind Testing Engineers should be suitably trained and qualified.

58. The loose grub screw found in the automatic contrivance was a potentially dangerous defect which could only have been discovered at the colliery by thorough internal examination, and design of the automatic contrivance should be improved to prevent this type of defect. Automatic contrivances, and the other parts of winding engines which are vital to safety, should be examined by persons with specialised skills, and provision for these examinations should be made in the manager's scheme of maintenance.

Training of winding enginemen

59. It became evident during the Inquiry that the winding enginemen used different operating techniques and the inconsistencies which resulted indicate a need for review of the training arrangements. The present practice of 'on the job' instruction is generally satisfactory but Colliery Engineers should play a more active part in this to ensure that the best methods of control are applied. In addition, a manual should be prepared for each winding engine and, without prejudice to the ability of enginemen to exercise their initiative and judgment, should explain the consequences of operation of the controls and protective devices.

Statutory provisions

60. Neither the Area Mechanical Engineer, the Area Electrical Engineer nor the Colliery Chief Engineer had statutory responsibilities although, in the

normal course of their duties, they would issue instructions to the Colliery Engineers who have statutory responsibilities. The view was expressed, and I agree, that the authority of these Engineers would be strengthened if they were appointed under section 1 of the Mines and Quarries Act 1954 or section 1 of the Mines Management Act 1971. The Area Overwind Testing Engineers should also be statutorily appointed.

61. Section 81 of the Mines and Quarries Act 1954, requires that 'All parts and working gear, whether fixed or movable, including the anchoring and fixing appliances, of all machinery and apparatus used as, or forming, part of the equipment of a mine, and all foundations in or to which any such appliances are anchored or fixed shall be of good construction, suitable material, adequate strength and free from patent defect, and shall be properly maintained'. It should be considered whether, in the circumstances, there has been a contravention of this section which it would have been practicable to avoid or prevent.

62. Evidence given at the Inquiry showed that the trunnion bearing did not operate as designed and caused fluctuating stresses to be induced in the centre rod of the spring nest which it could not sustain. R. Jeffrey, Senior Scientific Officer, Safety in Mines Research Establishment, said that any crack which had penetrated to a depth of $\frac{3}{8}$ inch could have been detected by ultrasonic tests without removing the rod, but not by visual examination with the unaided eye. There is uncertainty as to the frequency of ultrasonic testing which would have been necessary to discover the main pre-existing crack as its rate of propagation beyond $\frac{3}{8}$ inch could not be established. It appears that the persons at the colliery having responsibility for maintenance had no reason to suspect that the rod was overstressed and, therefore, did not appreciate the need for special methods of testing. Nevertheless, the rod was shown to be of inadequate strength for the stresses induced and the main pre-existing crack could have been found by available means of testing. Also, there was a precedent for this type of failure in a similar rod at Ollerton Colliery in 1961.

National Coal Board Instructions

63. During the investigation it was found that some keys and nuts in the brake system had not been secured in accordance with the requirements of National Coal Board Production Department Instruction PI 1956/10 which has been mandatory for 17 years. Several witnesses expressed the opinion that Production Department Instructions should be re-issued and reviewed periodically to ensure that their requirements are being implemented. I consider that a scheme for this purpose, which has been introduced in one National Coal Board Area, should be extended to all areas.

64. The Colliery Mechanical Engineer was not informed and did not hear about the accident until he was on his way to work at his usual time $1\frac{1}{2}$ hours later. He should have been informed immediately and colliery emergency procedures should be reviewed to ensure that all essential persons are notified.

Other matters

65. There was delay in identifying some of the casualties because their cap lamps and self rescuers were removed during the recovery operation. It was

suggested that, to avoid confusion, all persons going underground should wear an identification disc and this is worthy of further consideration.

66. A serious disadvantage of many colliery automatic telephone systems is their inability to select priority calls when the exchange is busy during an emergency. The National Coal Board has developed a system which will give priority to emergency calls and this should be incorporated in existing installations as soon as possible.

IMMEDIATE ACTION

67. Centre rods in all spring nests, similar to that involved in the accident, have already been changed and the National Coal Board is carrying out non-destructive tests on winding engine brake components and examining all winding apparatus to:

(*a*) identify all 'single line' components; and

(*b*) assess stresses in brake components.

In addition, schedules of mechanical and electrical examinations are being reviewed and action is being taken to ensure compliance with the requirements of Instruction PI 1956/10.

68. During 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 and immediately after the Inquiry I met representatives of the interested parties who agreed that a committee should be formed. The names of the persons who have agreed to serve on this committee are given in Appendix V. It is unlikely that the committee can report to me on your behalf before the end of 1974, but the National Coal Board has agreed to implement any interim decisions as the work proceeds.

69. At the first meeting of the committee on 3 December 1973 four sub-committees were formed to consider the engineering aspects of manriding in shafts and unwalkable outlets. Evidence at the Inquiry from H. A. W. Pettinger, Director, Otis Elevator Company Limited, indicated that some aspects of lift practice might be applicable to mining and he, with other representatives from industry, will be invited to serve on the sub-committees.

CONCLUSIONS

70. I conclude that:

(i) 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 pressures due to the spring nest, and the main lever could not rotate freely about the trunnion axle which had no practicable 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;

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

(iii) there can be no criticism of R. W. Kennan, the winding engineman who, as a last resort, attempted to stop the engine by pressing the emergency stop button provided for this purpose;

(iv) 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;

(v) 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.

Curtis, ...	... Board
Dunn, R. B.	Area Director
Fellows, J. E.	Draughtsman
Fleetwood, D.	Assistant Mechanical Engineer
Fox, W.	Colliery Mechanical Engineer
Furniss, H.	Contractor (Onsetter)
Godfrey, G.	Area Chief Engineer
Graves, C.	Mechanic
Hands, E. H.	Joint Managing Director, Blacks Equipment Limited
Harley, A. G.	Area Mechanical Engineer
Harvey, W. H.	Assistant Colliery Mechanical Engineer
Heywood, W. G.	Electrician
Hopkinson, J.	H.M. Inspector of Mechanical Engineering in Mines and Quarries
Horswill, V. P.	Photographer
Huckle, J. R.	Medical Room Attendant
Jackson, D. H.	Area Maintenance Engineer and Plant Pool Manager
Jeffrey, R.	Senior Scientific Officer, Safety in Mines Research Establishment
Jenkins, W. T.	Banksman
Kennan, R. W.	Winding Engineman
Lecutier, M. A.	Pathologist
Levers, C. C.	Colliery Electrical Engineer
Marshall, A.	President, Markham No. 2 Branch National Union of Mineworkers
Maxwell, J.	Reserve Face Worker

Name	*Occupation*
Munson, H. D.	Senior Principal Scientific Officer, Safety in Mines Research Establishment
Northard, J. H.	Deputy Director (Mining)
Peters, T. W.	Area Chief Mining Engineer
Pettinger, H. A. W.	Director, Otis Elevator Company Limited
Plant, J. A.	Colliery Chief Engineer
Pugh, J. F.	Area Metallurgist
Revill, E.	Assistant to the Manager
Rodgers, J.	Colliery General Manager
Stevenson, G. W.	Supplies Worker
Taylor, E. A.	Deputy Colliery Mechanical Engineer
Temple, E. T.	Winding Engineman
Tighe, R. L.	Undermanager
Treece, P.	Area Overwind Testing Engineer
Vallance, T.	Deputy
Vaughan, T. G.	Development Worker
Wall, T. L.	Principal Scientific Officer, Safety in Mines Research Establishment
Wallace, F. J.	Assistant Colliery Electrical Engineer
Ward, G.	Colliery Planned Maintenance Controller
Waterhouse, D.	Senior Scientific Officer, Safety in Mines Research Establishment
Wild, J.	Development Worker
Wingfield, R.	Area Medical Officer
Wood, P.	Head of Shafts and Winding Section National Coal Board Headquarters
Wykes, J. W.	Assistant Banksman
Yates, W. V.	Repairer

APPENDIX II

Names of the men who died or were seriously injured

Died	*Age*	*Occupation*
Joseph Birkin	60	Face Worker
Clarence Briggs	52	Deputy
Joseph William Brocklehurst ..	58	Deputy
Clifford Brooks	58	Deputy
Henry Chapman	48	Deputy
Gordon Richard Cooper	30	Development Worker
George Eyre	60	Gearhead Attendant
Michael Kilroy	53	Development Worker
Jan Kiminsky	58	Development Worker
Lucjam Plewinsky	59	General Worker
Frederick Reddish	53	Development Worker
Wilfred Rodgers	59	Face Worker
Charles Leonard Sissons	43	Road Repairer
Frank Stone	53	Road Repairer
Charles Richard Turner	60	Deputy
Albert Tyler	64	Back Repairer
Alfred White	57	Deputy
William Yates	62	Development Worker
Seriously injured		
Dennis Brothwell	44	Development Worker
Frank Cowley	43	Development Worker
Malcolm Joseph Cowley ..	29	Development Worker
James Reddish	25	Development Worker
Graham Richardson	34	Heavy Supplies Worker
George Denis Stone	41	Overman
Harry Taylor	47	Development Worker
Terence Thornley	18	Face Trainee
Terence Graham Vaughan ..	38	Development Worker
William Henry Watson	47	Face Worker
Richard Wrobels	44	Face Worker
Seriously injured in the rescue operation		
John Maxwell	35	Reserve Face Worker

APPENDIX III

Technical particulars of the winding apparatus

Upcast Shaft	
Diameter	15 feet (reduced to 10 feet in sump)
Depth (to lowest entrance) ..	1,407 feet
Guides	
Type	Rope
Number per cage	4
Disposition	Down one side
Method of suspension and tension	White metal filled swivel glands in headframe and tensioned by deadweights on frames in sump
Diameter	1½ inches
Weight suspended from each rope	Varies from 3·0 tons to 4·03 tons
Rubbing guides	
Type	Rope
Number	2
Disposition	On centre of shaft
Method of suspension and tension	White metal filled swivel glands in headframe and tensioned by deadweights in sump
Diameter	1½ inches
Weight suspended from each rope	2·14 tons
Headframe	
Construction	Brick tower with steel joist frame carrying pulleys
Number of pulleys	2
Diameter of pulleys	15 feet
Method of loading and unloading cages	Manual
Maximum overtravel distance before detaching hooks operate	15 feet 9 inches
Cages	
Number of decks per cage ..	2
Number of tubs per deck ..	2 tubs bottom deck only
Weight of cage	3 tons 3 hundredweights
Weight of suspension gear ..	10¼ hundredweights

Winding ropes	
Type	Locked coil
Diameter	1⅛ inches
Weight	3·09 pounds per foot
Nominal breaking load	76·78 tons
Drum	
Type	Parallel
Diameter	9 feet 0¾ inches
Rope distribution—dead turns ..	11
live turns ..	48½
Mechanical brake	
Number of brake paths ..	2
Diameter of brake paths ..	10 feet 3 inches
Width of brake paths	7·5 inches
Type of brake	Burns cradle
Type of friction lining	Ferodo FF fabric
Method of application	Spring
Control valve	Iversen type valve
Air pressure	80 pounds per square inch
Electric braking	
System	Re-generative
Winding duty	
Maximum number of men per cage	32 (16 in each deck)
Speeds	
Man riding maximum speed ..	27 feet per second
Nominal maximum winding speed	27 feet per second
Nominal maximum drum speed	56 revolutions per minute
Winding engine motor	
Method of coupling	Direct
Rated horsepower	440
Rated speed	56 revolutions per minute
Direct current voltage	440
Current	800 amperes

Motor generator set

Alternating current motor	
Type	3 phase, 50 hertz slip-ring induction
Rated horsepower	450
Voltage	3,300
Direct current generator	
Rating	360 kilowatts
Voltage	440
Speed	570 revolutions per minute
Direct current exciter	
Type	DH 11/38, 4 poles
Rating	21 kilowatts
Voltage	220
Full load current	95·5 amperes

Automatic contrivance

Type	Blacks torque controller (modified)

APPENDIX IV

Safety in Mines Research Establishment reports

Report No. 1 — *Examination and testing of spring nest rod and other components of a braking system.*
Authors — R. Jeffrey, O.B.E., B.Sc.
J. Deakin, B.Sc.

Report No. 2A — *Strain measurements on part of the braking system at Markham Colliery.*
Authors — G. A. C. Games, B.A.
P. K. Swift
D. Waterhouse, B.Sc. (Eng.), C.Eng., M.I.Mech.E.

Report No. 2B — *Simulation tests in the laboratory on parts of a braking system.*
Authors — G. A. C. Games, B.A.
P. K. Swift
D. Waterhouse, B.Sc. (Eng.), C.Eng., M.I.Mech.E.

Report No. 3 — *Tests on springs and a spring nest assembly.*
Authors — J. C. Moore
T. L. Wall, B.Eng. (Mech.), C.Eng., M.I.Mech.E.

Report No. 4 — *S.M.R.E. Investigations—Review and conclusions.*
Author — H. D. Munson, B.Sc. (Eng.), M.I.C.E., M. Weld Inst., F.I.M.H.

APPENDIX V

Members of the National Committee for Safety of Manriding in Shafts and Unwalkable Outlets

Chairman	W. J. Currie	Director of Engineering, National Coal Board
Deputy Chairman	S. Luxmore	H.M. Principal Electrical Inspector of Mines and Quarries, Department of Energy
	T. K. Clanzy	H.M. Principal Inspector of Mechanical Engineering in Mines and Quarries, Department of Energy
	H. D. Munson	Senior Principal Scientific Officer, Safety in Mines Research Establishment
	J. D. Blelloch	Chief Mechanical Engineer, National Coal Board, Headquarters
	R. Hartill	Chief Electrical Engineer, National Coal Board, Headquarters
	L. Walker	Chief Engineer (Maintenance and Engineering Services), National Coal Board, Headquarters
	J. N. L. Woodley	Deputy Director (Mechanical Engineering Division), National Coal Board Mining Research & Development Establishment
	H. Harrison	Mechanical/Electrical Inspector, National Union of Mineworkers
	A. Rushton	Representing The British Association of Colliery Management
	E. Loynes	Representing The Association of Mining Electrical and Mechanical Engineers
Secretary	R. F. Young	H.M. District Inspector of Mines and Quarries Department of Energy

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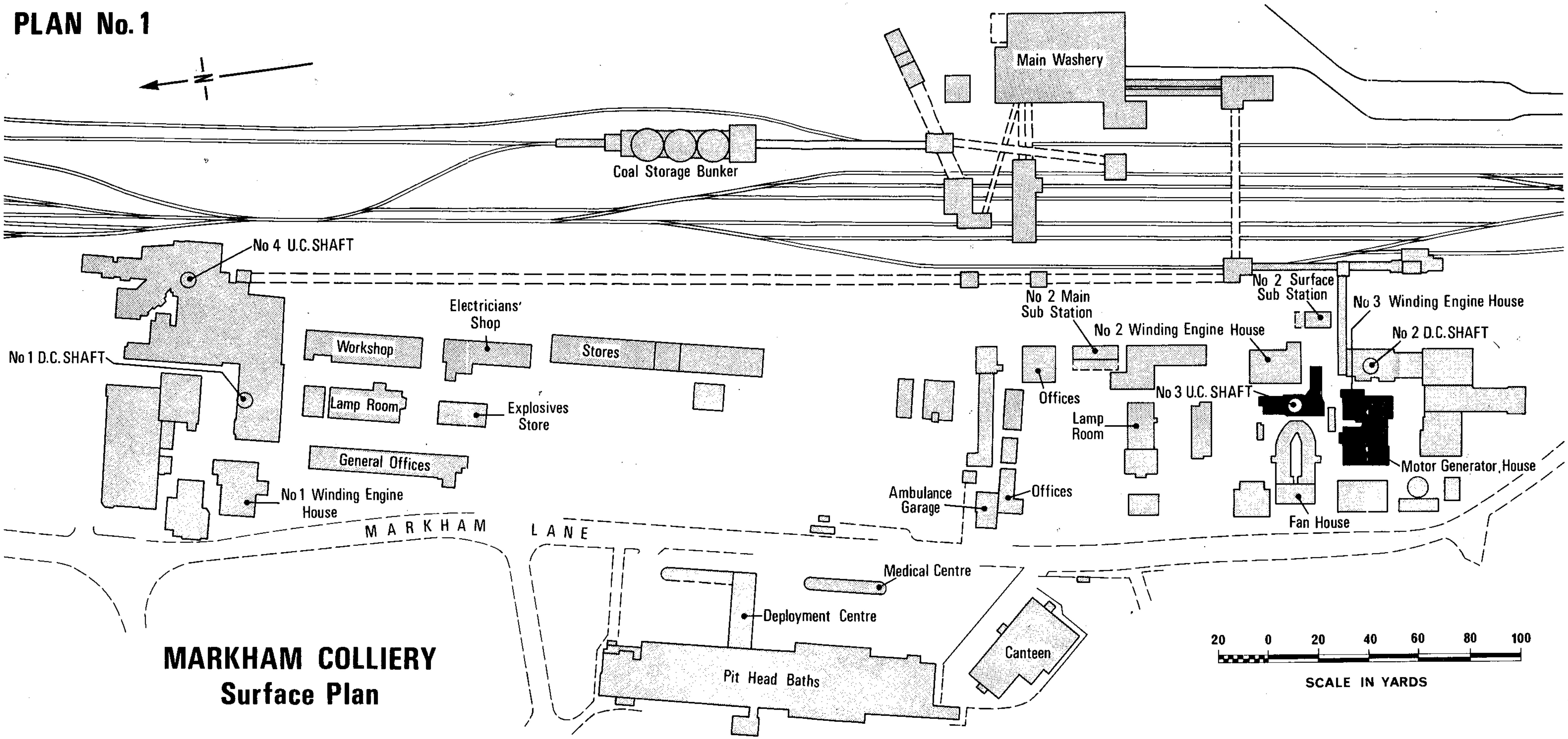
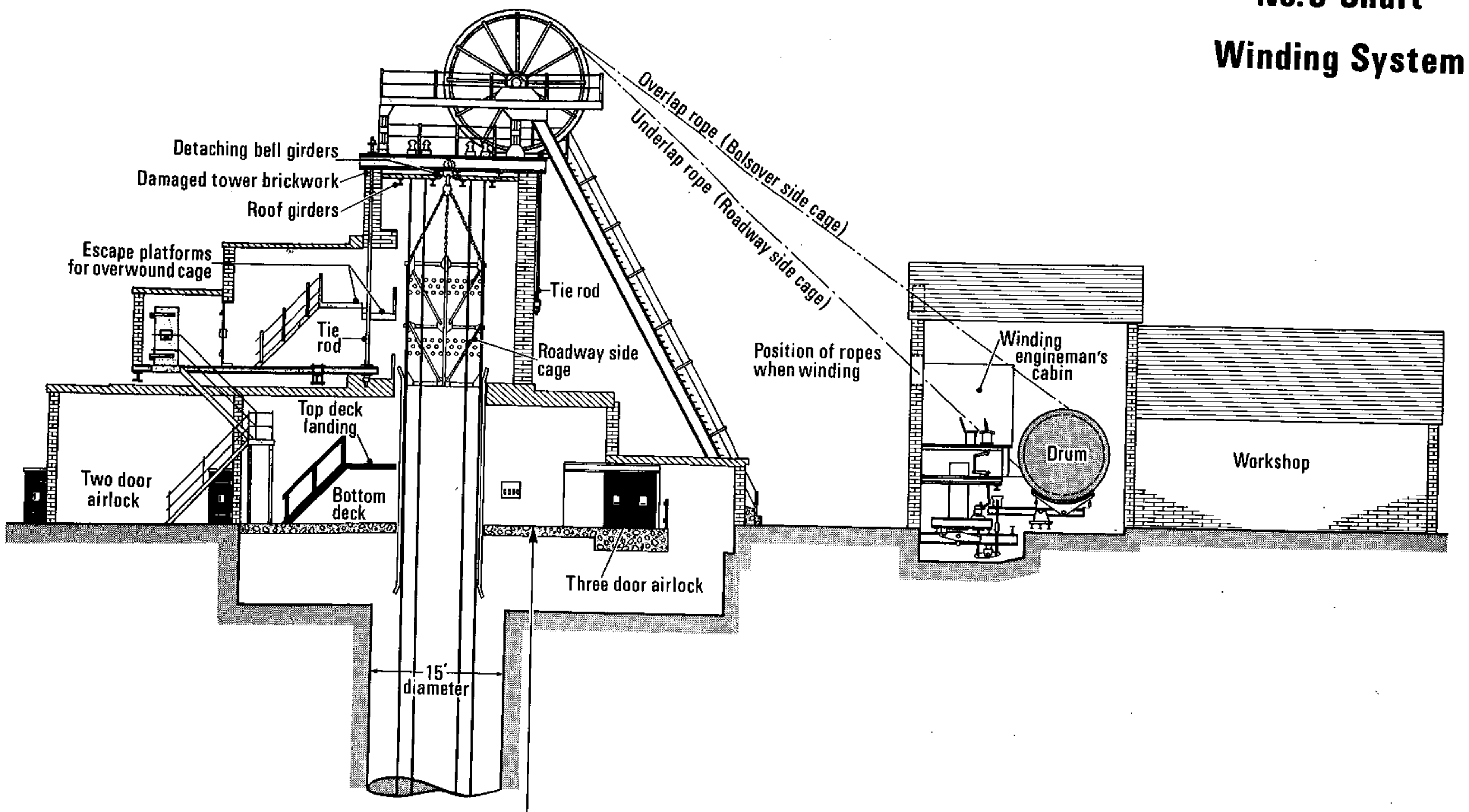
PLAN No. 1

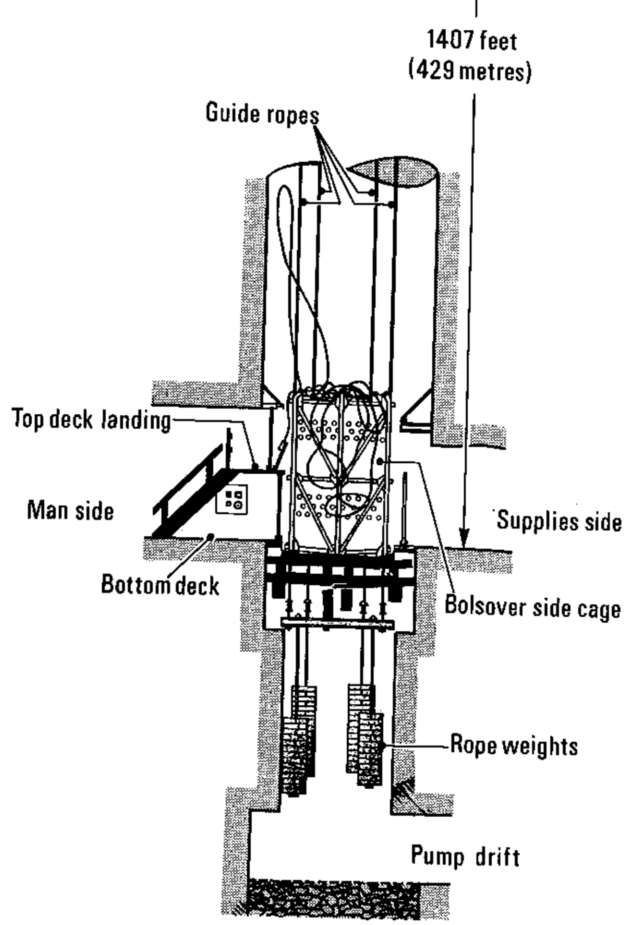


MARKHAM COLLIERY
Surface Plan

PLAN No. 2

MARKHAM COLLIERY
No. 3 Shaft
Winding System





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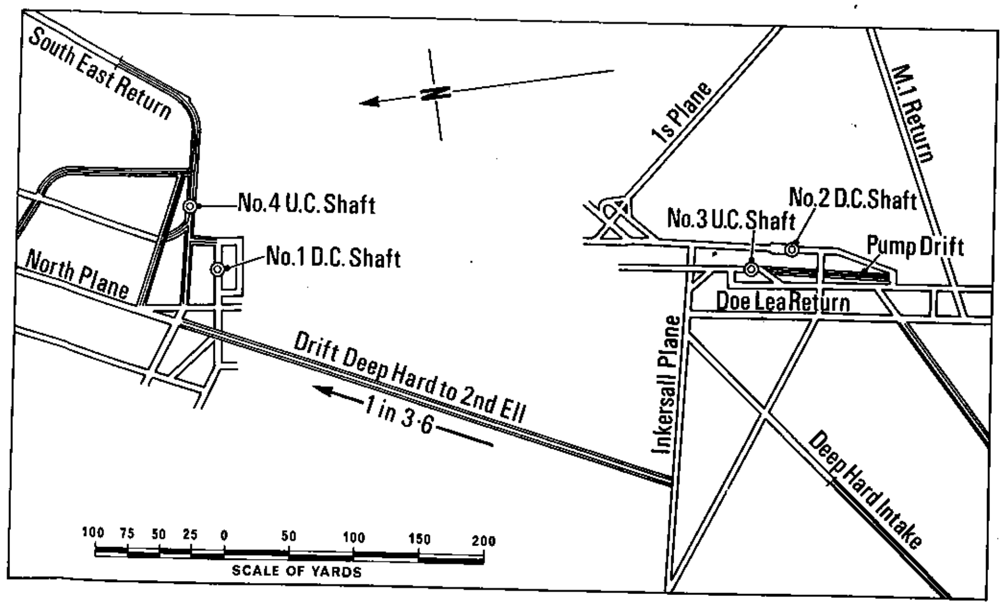

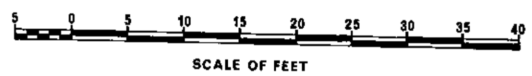

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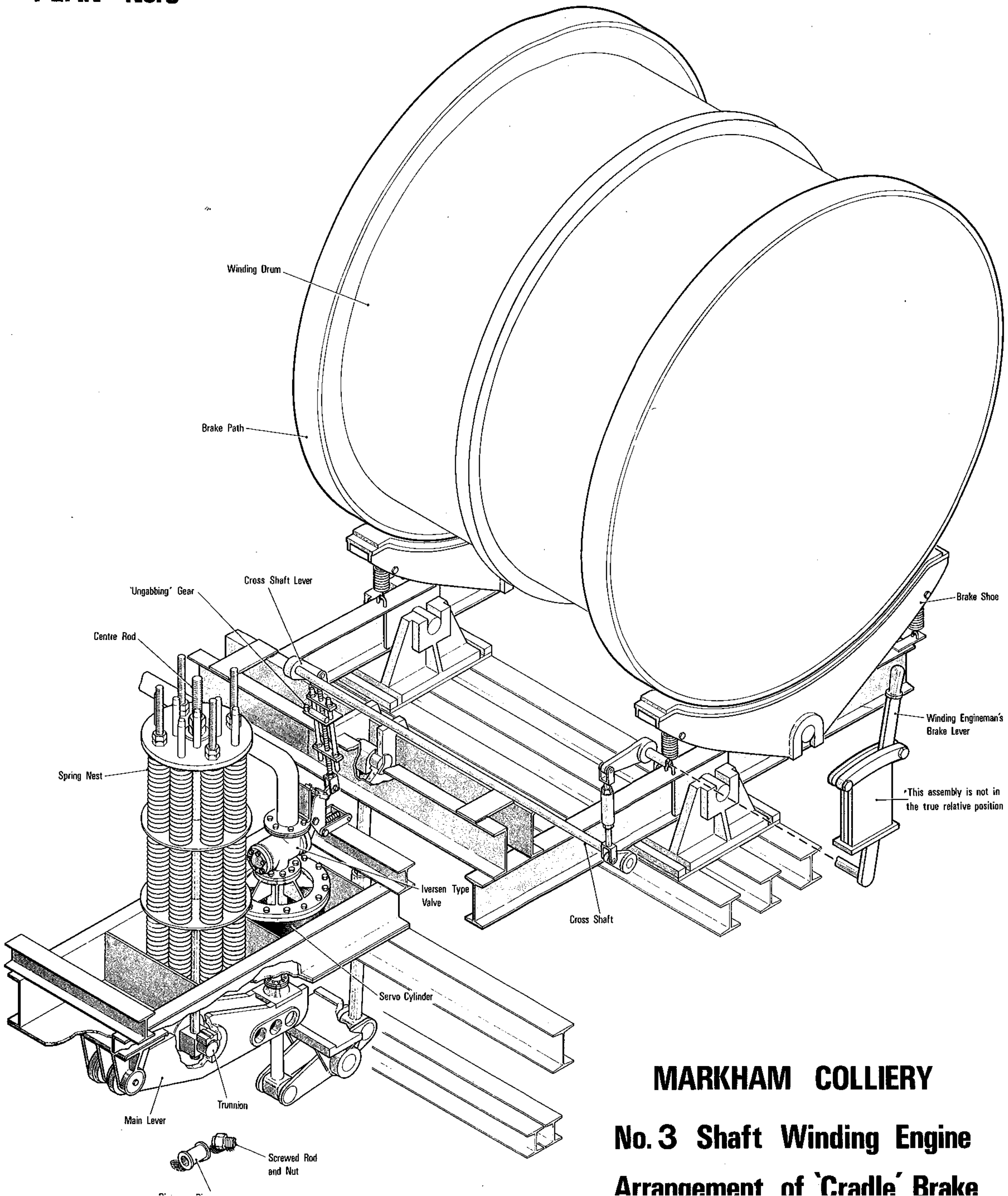

MARKHAM COLLIERY

No. 3 Shaft Winding Engine

Arrangement of 'Cradle' Brake