Department of Natural Resources, Mines and Energy

Investigation findings and recommendations

Winder brake failure at Osborne Mine on 1 March 2015

9 November 2018

Queensland Government

Executive summary

On 10 February 2015 there was a high potential incident at the Osborne Mine resulting in the rope on the fixed winder drum detaching from the skip/cage and the skip/cage being held up in the headframe.

Following this incident, on 1 March 2015, the brakes on the clutched drum failed to hold the counterweight which ended up at the bottom of the shaft. The remaining five or six turns of rope came off the drum and the rope broke at the anchor point on the drum. As the end of the rope came out of the winder house it caused considerable damage to the front window and the guard railing at the top of the head frame. One piece of the railing was found 105 m away on an internal mine road.

The winder without the counterweight rope

The mines inspectorate conducted an investigation that revealed since 2001 the method of testing the brakes was inconsistent with the OEM's recommendations and departed from demonstrating that the recommended factor of safety could be achieved.

As a result of the investigation, the inspectorate made a number of recommendations including ensuring that the original manufacturer's instructions are followed in regards to winder braking systems. Any variations from the original manufacturer's instructions must not raise the acceptable level of risk and must be documented.

With regard to the Static Brake Hold Test (SBHT) the following matters need to be assessed:

- All the conditions of operation, including production and maintenance, so that the maximum out of balance torque on individual winder brakes can be established.
- The required factor of safety for each brake when the maximum out of balance torque is applied to the winder.
- How the SBHT should be carried out to prove that the required factor of safety is achieved, the frequency of carrying out the SBHT, the persons responsible for carrying out the SBHT and the knowledge and skills required
- How the SBHT is recorded and the action to be taken if the SBHT fails.

In relation to the brake calipers, consider spring force testing, monitoring of the air gap and a system that can identify leakage from individual calipers.

In the event that the brake path becomes contaminated, the manufacturer's instructions should be followed and should include cleaning the brake path and replacing all the brake linings and identifying the source of the contamination to prevent further contamination.

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Purpose of document

An investigation was undertaken by the mines inspectorate to determine the cause of the winder incident on 1 March 2015. The investigation revealed that there was a drift over time from the original manufacturer's instructions which departed from demonstrating that the recommended factor of safety could be achieved.

This document provides a summary of the key findings, conclusions and recommendations to prevent a recurrence of a similar incident. In particular the inspectorate would like to highlight the need to ensure that the original manufacturer's instructions are followed in regards to winder braking systems. Any variations from the original manufacturer's instructions must not raise the acceptable level of risk and must be documented.

Mine details

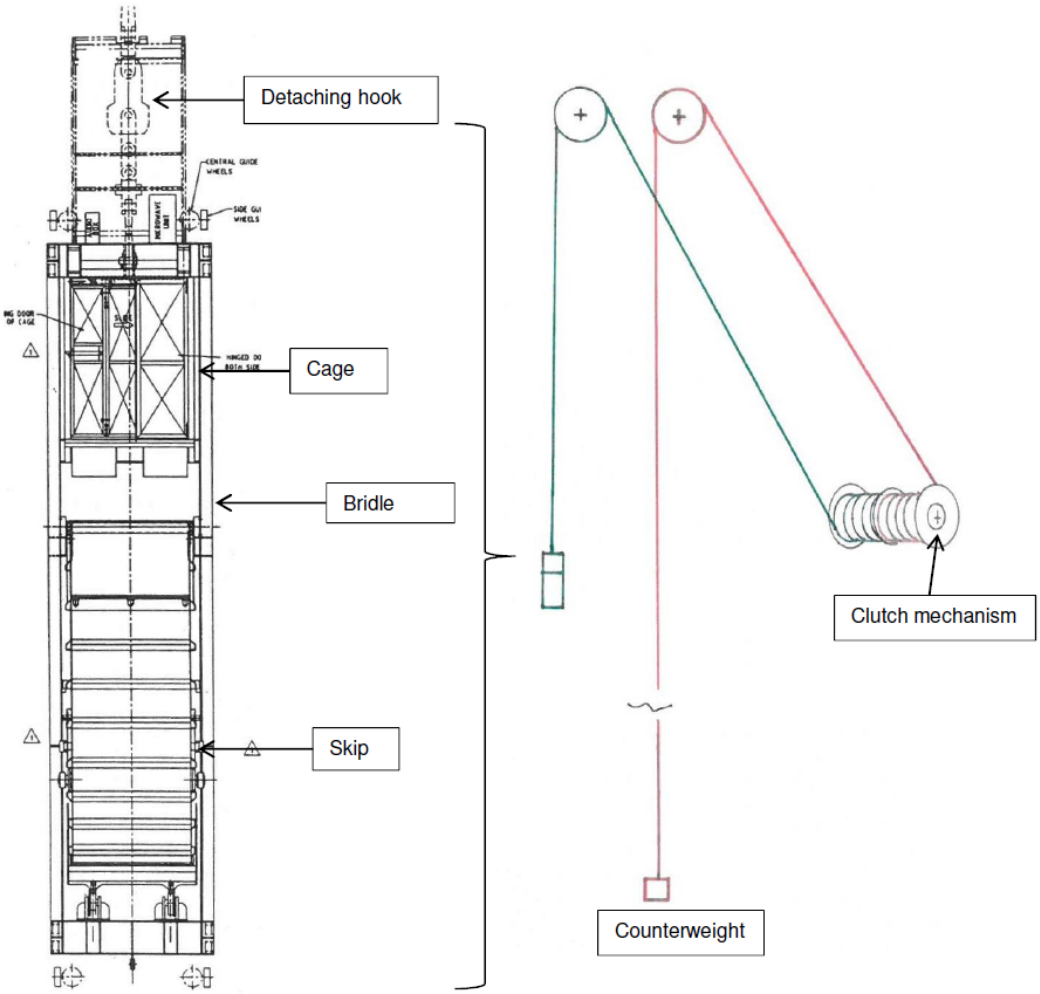
Osborne Mine is a copper/gold mine and processing operation located approximately 195 kilometres south-east of Mount Isa in north-west Queensland. Mined ore is processed through an underground primary crusher and then hoisted to the surface via a 700 metre shaft and a double drum winder with a skip/cage combination and counterweight. Operations were commenced by Placer Dome Incorporated in 1995 as an open pit mine, before transitioning to a solely underground operation in 1997, accessed via a portal in the open pit. The underground crushing and hoisting system was commissioned in 1998.

Details of the winding system

The winder used at the Osborne Mine is a double drum winder. A drawing of the skip/cage arrangement and a sketch of the winding system are shown below. The rope is underwound on the fixed drum (shown in green) and attached to the skip/cage. The rope is overwound on the clutched drum (shown in red) and attached to the counterweight. The counterweight and the skip/cage travel in opposite directions in their respective 700 m shaft compartments as the drums rotate.

The fixed drum is always connected to the drive. The clutched drum can be disengaged from the drive and then becomes entirely dependent upon its own brake to hold the counterweight. Each drum has an independent braking system with a brake disc and eight brake calipers on each drum.

The original equipment manufacturer (OEM) of the winder was GEC Alsthom Australia Ltd. In 1998 Alsthom changed its name to Alstom and United Group Ltd (UGL) took over the company on 16 September 2005.



Drawing of the skip/cage and sketch of the winding system

Maximum out of balance torque

The winder OEM states that the maximum out of balance torque occurs when the counterweight is at the bottom of the shaft and the clutched drum is disengaged.

Static brake hold test

The Static Brake Hold Test (SBHT) is a method of checking that the brakes will hold the counterweight, when it is at the bottom of the shaft and the clutched drum is disengaged, with the required Factor of Safety (FOS). The FOS, for a single drum of the system, as designed and approved is not less than 1.5 times the designed maximum out of balance torque. For this winder, the SBHT is applied separately to the clutched and fixed drum. Current is applied via a control setting called torque reference (TR). TR is a percentage of the available motor current that the control system applies during the test.

Legislation relevant to the static brake hold test

The winder was designed to comply with Metalliferous Mining Regulations 1985. It was approved for use by the Mines Inspectorate on 6 October 1998.

The Metalliferous Mining Regulations 1985 stated:

> *"6.2.7(d) The brakes of a winding engine shall be capable of exerting a total torque of not less than 2.5 times the designed maximum out of balance static torque under all conditions of operation.*
>
> *6.2.7(e) The brakes shall be tested to ensure that the brakes of each drum are capable of exerting a torque of not less than 1.5 times the designed maximum out of balance static torque."*

The Mining and Quarrying Safety and Health Regulation 2017 section 108 Monitoring is applicable and states:

a) *A person who has an obligation under the Act to manage risk at a mine in relation to monitoring plant must monitor the plant's use, condition and performance to – detect any deterioration causing an unacceptable level of risk.*

Incident description

On 10 February 2015 there was a high potential incident at the Osborne Mine production winder and shaft resulting in the rope on the fixed winder drum detaching from the skip/cage and the skip/cage being held up in the headframe.

Following this incident, on 1 March 2015, the brakes on the clutched drum failed to hold the counterweight which ended up at the bottom of the shaft. The remaining five or six turns of rope came off the drum until the rope broke. As the end of the rope came out of the winder house it caused considerable damage to the front window and the guardrailing at the top of the head frame. One piece of the guardrailing was found 105 m away on an internal mine road.

Access ladder and platform to the top window of winder house before the second incident

Damage to the front of the winder house after the second incident

Damage to the guardrailing at the top of the headframe

Piece of guardrailing found 105 m from headframe

Investigation findings

Investigation found that there was a drift over time from the original equipment manufacturer's instructions for testing and maintenance. The method of testing the brakes became inconsistent with the OEMs recommendations and departed from demonstrating that the recommended FOS could be achieved. This document provides a summary of the findings, conclusions and recommendations.

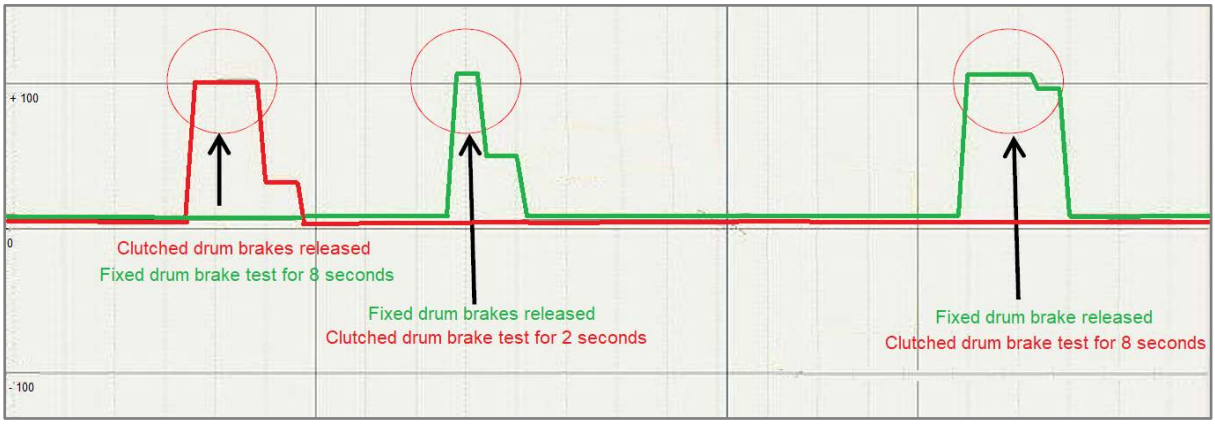
Incident details

On the day of the first incident, on 10 February 2015, there were two consecutive brake test failures which showed that the factor of safety was less than 1.22. As a result, the brake disc was cleaned but when an additional SBHT was conducted it also failed. The winder was then run to *burn off* the cleaning fluid by applying dynamic braking. When the skip/cage was ascending, the brakes failed to stop, the rope detached and the skip/cage became suspended in the headframe.

Following the incident, there were four SBHTs carried out on individual calipers by a consultant. The reported FOS was 2.24 but there was no mention of when the clutched drum was disengaged or the effect of the slack rope attached to the drum. There were also four SBHTs completed by winder drivers when the conveyances were at mid-shaft. The power applied was recorded for only one of those tests which was TR of 74% which only proved an FOS of 1.09 when the counterweight was near mid-shaft and the clutched drum was disengaged.

When asked in an interview why the SBHTs were carried out at mid-shaft one winder driver replied that it was too difficult to bring the counterweight back up. Another confirmed that there were no formal procedures or instructions to complete the test mid-shaft but it had worked for 13 and half years and so he accepted it.

The last of these four SBHTs was done on the morning of the incident and the Citect screen shot of the chart is shown below. The timeline goes from left to right. The green trend lines show the fixed drum brake is released while the clutched drum brake is being tested.



Static brake hold tests on day of incident

The first SBHT on the clutched drum appears to have failed because it lasts only 2 seconds instead of 8 seconds. The second SBHT shows a pass result but no TR is recorded. When asked during a record of interview whether it was possible that the first SBHT on the clutch drum had failed and the test had be redone, the winder driver replied: "*We've redone it……Yep, yep. That's possible.*"

Upgrade to winding system

The winding system was upgraded in 2001 to maximise the hoisting throughput and to minimise a prevailing problem being experienced with counterweight and skip-cage rope oscillation.

The OEM described in their report how to carry out a static brake hold test. They stated that the maximum out of balance torque on the winder occurs when the counterweight is near the bottom of the shaft and the clutched drum is disengaged. The OEM stated that the clutched drum brake must have an FOS of 1.5 in this situation.

Power cannot be applied to the clutched drum while the clutch is disengaged therefore the tests needed to be conducted while the clutched drum was engaged and the test power increased to compensate for the balance effect for the skip on the system.

The power required to provide an FOS of 1.5 is 4950 A which is equivalent to a TR of 100.2%. Since the torque setting is limited to 100%, 4940 A should be used.

In the actual commissioning test, the OEM applied 4500 A which provides a torque ratio (TR) of 91% and proved an FOS of 1.4.

Operating procedures

Work instruction – de-clutching the winder drums

The 2004 work instruction for disengaging the clutched drums is in line with the OEM procedure for carrying out an SBHT with the exception that only a TR of 50% (2740 A) was applied. As a result the proven FOS on the clutched drum brake would be 1.05, not 1.5 as required by the OEM, when the counterweight is near the bottom of the shaft and the clutched drum is disengaged.

Mine procedure – Brake hold test before declutching

A procedure to perform a brake hold test before declutching was established in September 2007 by a working party of content experts that consisted of three winder drivers and one winder driver/assessor and was approved by the mine management. The procedure specified that the power to be applied to the brakes was 70% TR (3458 A). This method provided an FOS of 1.22 on the clutched drum brake when the counterweight was near the bottom of the shaft and the clutched drum was disengaged.

Task	Steps	Key Points
1. Before the winder clutch is disengaged a brake hold test must be performed on each drum as follows.	a) With the cage parked below the brace, select mode 3, brake hold test with 70% torque setting. b) Select the clutched drum brakes and attempt to raise the skip to simulate the maximum out of balance condition. c) Move the cage and repeat the brake hold test with the fixed drum brakes selected. d) If the drums move during the brake hold test the brakes will have to be checked and tested successfully before the clutch is disengaged.	

Mine SBHT procedure 2007

Re-commissioning

In March 2008, within a period of eight days the clutched drum brake failed three times to hold the counterweight after the clutched drum was disengaged when the counterweight was at mid-shaft.

The accepted remedy for the brake failure was to clean the brake disc without further enquiries. The mine's Investigation Report does not mention if an SBHT was carried out prior to the clutched drum being disengaged in accordance with the mine's procedure. The cause of the brake failure was stated to be dust on the brake disc and excessive caliper air gap.

Following on from the incident, the winder was re-commissioned by UGL, in September 2008. Although UGL applied a torque ratio (TR) of 100%, the mine procedure remained unchanged stating that only a torque ratio of 70% was required.

Maintenance

Static brake hold tests

The Static Brake Hold Test (SBHT) was required to be carried out in accordance with the 28 day Electrical PM and several persons stated that the SBHT was carried out weekly when the seven day mechanical inspection was carried out. Brake failures during SBHTs were not recorded because they occurred during testing.

Investigation revealed that between 2001 and 2015 the SBHTs drifted away from the OEM specifications as follows:

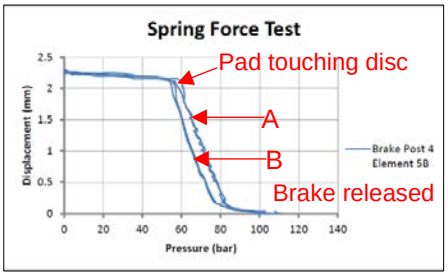
- According to a winder driver, from 2008 to 2010, SBHTs were done by applying a TR of 99% (4890A) which proved a factor of safety of 1.5 on the clutched drum brake when the counterweight was near the bottom to shaft and the clutched drum was disengaged.
- One winder consultant used a standard format for the SBHTs they carried out in 2012, 2013 and 2014. The consultant only considered the *normal maximum out of balance load* and did not consider the OEM stated maximum out of balance torque when the counterweight was at near the bottom of the shaft and the clutched drum was disengaged. In 2012 the consultant determined that the factor of safety was >2.5 for each brake when the clutched drum was engaged. However calculations reveal that the factor of safety on the clutched drum brake was 1.4 when the clutched drum was disengaged and the counterweight was near the bottom of the shaft.
- In August 2012, in response to an enquiry by the Inspectorate, the mine indicated that the SBHT was being carried out at the correct test position. However the response also stated that they did 90%-99% at 3500-4000 amps and the consultants were happy for them to do 50%-70% to around 2000 A.
- In 2014 a consultant applied 3000 A to the fixed drum brake and the clutched drum brake in turn and determined that the factor of safety was >2.15 for each brake when the clutched drum was engaged. However when calculating the factor of safety when the clutched drum was disengaged and the counterweight was near the bottom of the shaft, it only proved to be 1.13.

Spring force tests

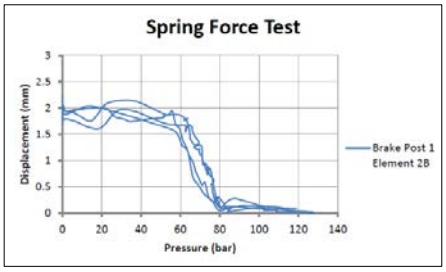
Spring force tests are used to determine the condition of brake calipers and the results are displayed on a pressure/displacement chart. The external pressure is generated by a hydraulic hand pump. The displacement (as shown in the chart) is the inverse of the air gap i.e. when the displacement is zero, the air gap is at its maximum and the caliper is fully retracted.

Path A shows the external pressure increasing until the brake is fully released and Path B shows the external pressure decreasing until the pad comes into contact with the disc. At this point the caliper is not applying any pressure to the brake disc. The pressure applied by the hand pump is an indication of the pressure the caliper will apply to the disc as the external pressure is reduced to zero. The slight variation or hysteresis in the paths is due to internal friction. Typically when the disc brake calipers are new the hysteresis can be in the range of 9% to 12%. The OEM of the brake caliper state in their instruction manual that springs should be changed if the hysteresis is 12.5% or more.

The chart on the right displays spring force tests conducted in January 2012. It shows a caliper on the clutched drum brake with an unknown problem. Four calipers on this drum had a similar problem and were listed for immediate attention.

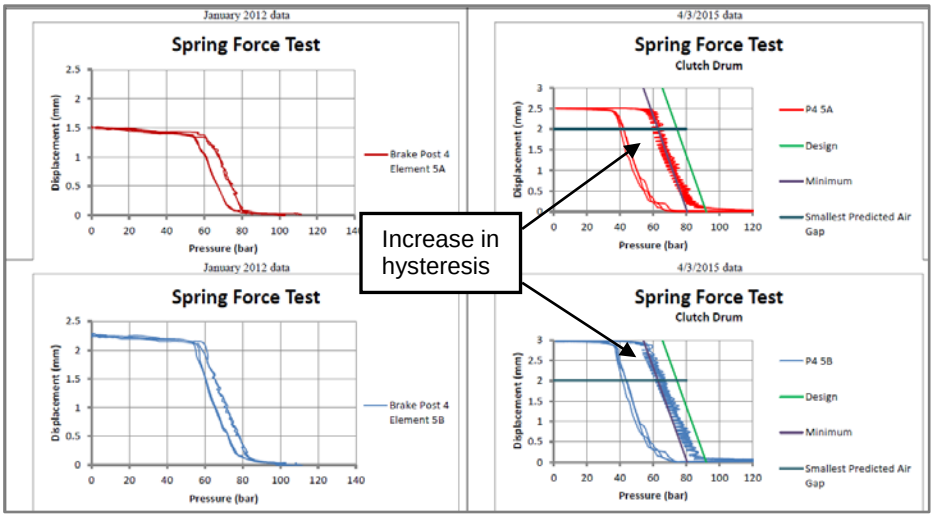


Acceptable Spring Force



Unknown problem – January 2012

Comparison of results of spring force tests between 2012 and 2015 show an increase in hysteresis to about 30%. This could result in a significant reduction in the pad to disc forces and brake holding capacity. In addition, the air gap settings on the brakes were greater than specifications which contributed to lowering the braking force.



Spring Force Tests comparison of caliper on clutched

Brake disc contamination

On two occasions consultants observed contamination on the inside of the clutched drum disc brake, once in 2012 and again in 2014. The consultant's May 2014 report stated that the brake disc surface on the inner side of the clutched drum appeared to be contaminated by oil and recommended cleaning the disc surface with a suitable cleaning fluid and to remove and clean the pads one by one.

The consultant's reports did not make reference to finding the source of the contamination and gave advice that was contrary to the manufacturer's maintenance instructions for the brake calipers that states *"*If friction pads become fouled with fluid they must be replaced after curing the leak and the disc(s) wiped clean*".*

From May 2014 until the incident on 10 February 2015, no evidence was found that the brake calipers were changed out and no new brake pads were installed. The practice of cleaning the contaminated brake disc when the SBHT failed became normal and was endorsed by consultants.

Clutched drum brake disc contaminated with oil

Conclusions

The investigation found a number of contributing factors including:

- The OEM's recommendations stated that the test power required to provide an FOS of 1.5 is 4940 A which is equivalent to a TR of 100%. The OEM also stated that the static brake hold test must be undertaken when the counterweight is near the bottom of the shaft. Since 2001 the method of testing the brakes was inconsistent with the OEM's recommendations:
    - Work instruction developed in 2004 stated that the SBHT was to be done at TR of 50% (2740 A).
    - Brake hold test procedure established in 2007 stated that the power applied to the brakes was TR 70% (3458 A).
    - Consultants did not state the FOS when the clutched drum was disengaged.
    - Tests carried out by the mine during the recovery from the incident on 10 February 2015 were completed with the conveyances at the wrong position.
    - Some SBHTs carried out by the mine during operations were carried out with the conveyances at the wrong position over the last thirteen years.
- Incorrect air gap settings that lower the braking force.
- Contaminated brake pads were cleaned rather than replaced which is inconsistent with manufacturer's maintenance instructions.
- The calipers had excessive internal friction.

Recommended actions

The OEM instructions with regard to winder braking systems should be followed. Any variations from the OEM instructions with regard to winder braking systems must not raise the acceptable level of risk and must be documented.

With regard to the SBHT the following matters need to be determined:

- All the conditions of operation, including production and maintenance, so that the maximum out of balance torque on individual winder brakes can be established.
- The required FOS for each brake when the maximum out of balance torque is applied to the winder.
- How the SBHT should be carried out to prove that the required FOS exists, the frequency of carrying out the SBHT, the persons responsible for carrying out the SBHT and the knowledge and skills required
- How the SBHT is recorded and the action to be taken if the SBHT fails.

In relation to the brake calipers, consider spring force testing, monitoring of the air gap and a system that can identify leakage from individual calipers.

In the event that the brake path becomes contaminated, the manufacturer's instructions should be followed and should include cleaning the brake path and replacing all the brake linings and identifying the source of the contamination to prevent further contamination.