Planning & Environment
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REPORT | RESOURCES REGULATOR

# Investigation report

## Report into the incident involving a worker at Ulan West Operations on 26 November 2015

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# Executive summary

## What happened

A worker was injured when a pipe end known as a ‘pressure manifold’ separated from the end of a polypropylene pipe during a pressurised leak test at Ulan West Operations on 26 November 2015.

Contract workers were testing and checking the integrity of recently recovered polypropylene pipes from the underground workings of the mine.

The recovered pipes were visually inspected for damage before being pressure leak tested using compressed air from the mine’s reticulated compressed air system.

Pressurised leak testing required a pressure manifold and pressure gauge manifold to be fitted to either end of the pipe line, with the pressure manifold coupled to the mine’s compressed air supply using a flexible hose.

When the pipes were ready to be tested, compressed air was directed into the pipe via a gate valve that was isolated once the pressure in the pipe equalled the mine’s compressed air supply of approximately 870kPa. The pressurised leak testing then began.

The pressure drop within the pipe over a 15-minute test period was recorded during the pressurised leak test. If there was no drop in pressure, the pipe would be considered fit for reuse.

The testing of the pipes was conducted in accordance with the work procedure provided by the mine.

The incident occurred when the workers were testing the last of the group of pipes. The air supply was connected to one of the pipes and turned on. As the pressure rose to approximately 650kPa, the swaged pipe end fitting that was coupled to the pressure manifold suddenly separated from the pipe end and knocked a worker off his feet.

Figure 1 shows the pressure manifold and swaged end fitting.

After the incident, the pressure manifold and swaged end fitting were found separated from the pipe end and both were about 6 metres apart.

The worker suffered leg, hand and facial injuries that required him to be hospitalised for treatment.

Further information on this incident can be found in Safety alert: Worker seriously injured when pipe assembly failed pressure test.

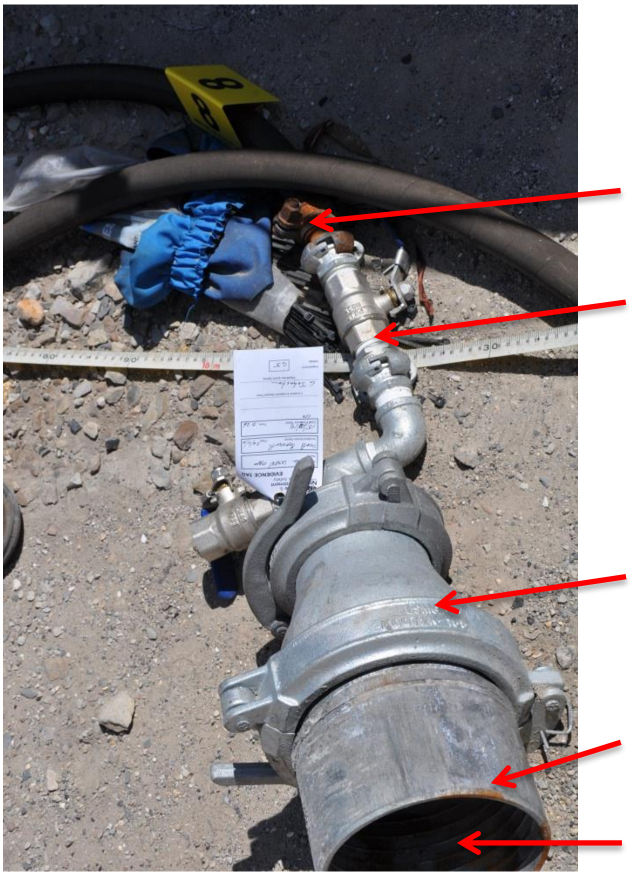
## Inert pipeline

The purpose of the inert pipeline was to deliver nitrogen gas to underground workings of the mine in order to suppress any potential outbreak of fire in the event of spontaneous combustion of coal in the mined out areas of the mine (goaf). The nitrogen was being delivered into the pipeline from a surface nitrogen generator that was close to the compressed air station on the surface.

Nitrogen was pumped down a steel pipeline from the surface, along the main travel road to the main gate entry of longwall panels. The inert polypropylene pipe was connected into this steel pipeline. The polypropylene pipeline ran from the longwall main gate entry to the longwall goaf area.

As the longwall goaf moved back towards the main gate entry, the polypropylene pipes were recovered and transported back to the surface of the mine to be reused in another longwall gate road.

**Figure 1 - Photograph of pressure manifold and swaged pipe end.**




# Why the controls failed

1. The investigation found the connection between the pipe coupling and the pipe separated because:
    a. there was dimensional incompatibility between the pipe size and swaged end size. The pipe was found to be manufactured outside of design tolerance specifications
    b. the pipe assemblies were not re-swaged. A similar incident at the mine in February 2015 identified the need to revise the pipes’ crimping dimensions due to pipe/fitting size incompatibility
    c. the recovery process from underground and the subsequent transportation to and from the surface did not consider potential damage to the swage fitting/pipe connections
    d. there was relative movement between the pipe and swaged fitting, refer to Figure 9 and Figure 12. This was most likely from the installation, transportation, recovery process imposing tension and bending forces to the swage fitting/pipe connection.
2. The investigation also found that energy from the testing of the pipe had the potential to injure workers because:
    a. no consideration was given to the sudden failure of the swaged end during the process of pressurised leak testing

b. workers involved in the pressurised leak testing considered the process safe because the pipes were being pressurised to a working pressure of 870 kPa and the polypropylene pipes showed a work pressure rating of 900 kPa

c. workers were not given a copy of the recommendations from a similar event that occurred in February 2015. There were a number of control measures identified and they were not included in the safe work procedure (SWP).

d. the SWP provided to the workers

    i. listed isolation and stored pressure as the only hazards. It did not identify sudden failure and projectile energy as a hazard.

    ii. was not applicable for pressurised leak testing of many polypropylene pipes at ground level when stacked alongside each other, refer to Figure 3. The SWP was for pressurised leak testing polypropylene pipes when installed and hung from the roof underground.

e. the workers were

    i. not trained in the process of pressurised leak testing of polypropylene pipe, and

    ii. undertaking this task for the first time.

# Recommendations to prevent a reoccurrence

## 1. Integrity of swaged fitting to non-metallic pipe connection

a) Manufacturers of non-metallic pressure pipe (polypropylene pipe that is injection moulded or similar) should have robust quality control systems to ensure:

    i. defects in pipe critical tolerances are quickly identified (real time) in the manufacturing process ensuring out-of specification pipes are not placed in the field i.e. parameters such as pipe outside dimension, pipe ovality, pipe wall thickness, pipe ends cut squarely.

    ii. pipe is only supplied for use if that pipe is compliant with design tolerance specifications

    iii. a full battery of tests are carried out and endorsed by the designer, where changes are made to raw material, formulation or the manufacturing process. This is to ensure the changes do not adversely affect pipe performance as intended by the designer.

b) Consideration should be given to only providing non-metallic pressure pipes with factory-swaged ends and not field-swaged ends or field swaged double couplings.

c) When an incident occurs and the designer manufacturer or supplier provides recommendations to prevent reoccurrence, those recommendations should be implemented.

d) The swaging of non-metallic pipe fittings should be carried out on new pipe of correct tolerance. Used (second hand) pipe may not be dimensionally compatible with the swaged fittings.

## 2. Pressurised leak testing of non-metallic pressure pipe assemblies

a) A SWP in relation to non-metallic pressure pipe testing should:

    i. consider all hazards associated with pressure leak testing, including a sudden failure

    ii. be representative of the actual task being carried out

    iii. be prepared in consultation with the manager of mechanical engineering.

b) The use of work authorisation/permits/SWPs should not be limited to contractors undertaking work at the mine.

c) Pressure leak testing of a non-metallic pressure pipe assembly at any time should only be carried out when necessary. Where pressure leak testing is necessary, the use of a non-compressible medium such as water should be considered.

d) When an abnormality is identified with a procedure or process, every effort should be made to stop the process immediately until the abnormality has been rectified and the process or procedure is reauthorised.

e) The establishment of strict controls, e.g. well-defined go-no-go areas, barricaded areas, the use of guarding and/or mechanical restraints, provision for remote activation of energy source and remote recording/monitoring of the pressure energy should be undertaken.

f) The person undertaking pressure leak testing of pipe assemblies that involves the use of a pressurised medium should be fully trained and made aware of all risks associated with the task. This will assist with the implementation of suitable safe guards to prevent injury in the event of sudden failures.

## 3. Handling of non-metallic pressure pipe

a) All duty holders of non-metallic type pressure pipes should consider the full life cycle of the pipe including:

   i. intended use

   ii. methods of transport

   iii. means to lift pipe assemblies to the mine roof

   iv. pressure leak testing methods

   v. means to swage pipe fittings and join pipes together in the field

   vi. the number of pipes intended to be joined during transport.

b) A SWP in relation to the handling of non-metallic pressure pipe should:

   i. be representative of the actual task being carried out

   ii. consider potential damage to the non-metallic pressure pipe assembly during transportation throughout the mine, installation and recovery

   iii. be prepared in consultation with the manager of mechanical engineering.

c) Dragging of pipes should be avoided where possible as this can lead to joints being stressed and resulting in sudden failures when pipes are placed into service.

d) To reduce the influence of external forces being applied to pipes and joiners, consideration should be given to providing pipes of a single length only without double couplings being fitted.

# Contents

# 1. Background

## 1.1. The mine

Ulan West Mine operates an underground mine, extracting coal via longwall operations from the Ulan coal seam.

The coal seam has a history of spontaneous ignitions of coal from the goaf area behind a retreating longwall.

A technical review (by the technical services department) and risk assessment were undertaken by the mine with a proposal to install a pipeline from a surface nitrogen plant to the underground parts of mine via pre-driven roadways.

Following the technical review, it was decided to buy a polypropylene pipe from Pipelion Pty Ltd. The pipe was marketed as being fire resistant and anti-static (FRAS) and suitable for use for inert gas.

The product was manufactured by UGM Mining Solutions Pty Ltd (UGM Mining Solutions) at Teralba and transported by road in 10 m lengths. At Ulan West site, the 10 m sections of pipe were joined together into pipe lengths of up to 50 m using a series of swaged joiners.

## 1.2. The purpose of the incident pipe

The incident pipe was a polypropylene Pipelion beige inert pipe (the pipe) installed at Ulan for the purpose of:

a. delivering inert gas from the surface gas generator to the underground workings of the mine in the event of a spontaneous combustion event.

b. The pipe offered a number of advantages over the use of conventional steel shouldered pipes including:

    i. maximum lengths could be tailored to the customer’s request

    ii. having greater flexibility over conventional steel pipes of the same dimensions

    iii. being colour coded for ease of identification of fluid type being conveyed by the pipe

    iv. being weight saving over conventional steel pipes of the same dimensions.

c. The pipe was beige in colour and was intended for inert gas, by the manufacturer. See pipelion.com.au/product-range

d. Specification of the pipe and fittings:

    i. Pipe working pressure: = 1,000 kPa

    ii. Fittings working pressures:

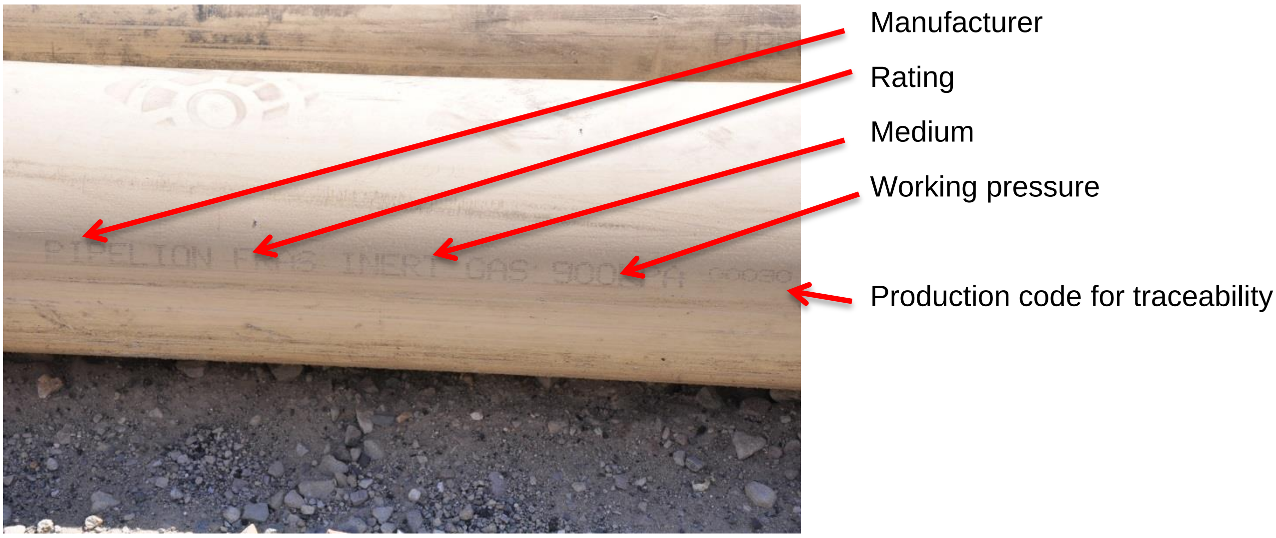
        i. Shouldered end: = 2,100 kPa

        ii. Dual coupling: = 2,100 kPa

    iii. Pipe outside diameter: = 160 mm

e. Information supplied by the mine indicates the pipe would have been subjected to a maximum working pressure of 870 kPa at Ulan West Mine.

Figure 2 – Pipelion specification marking.



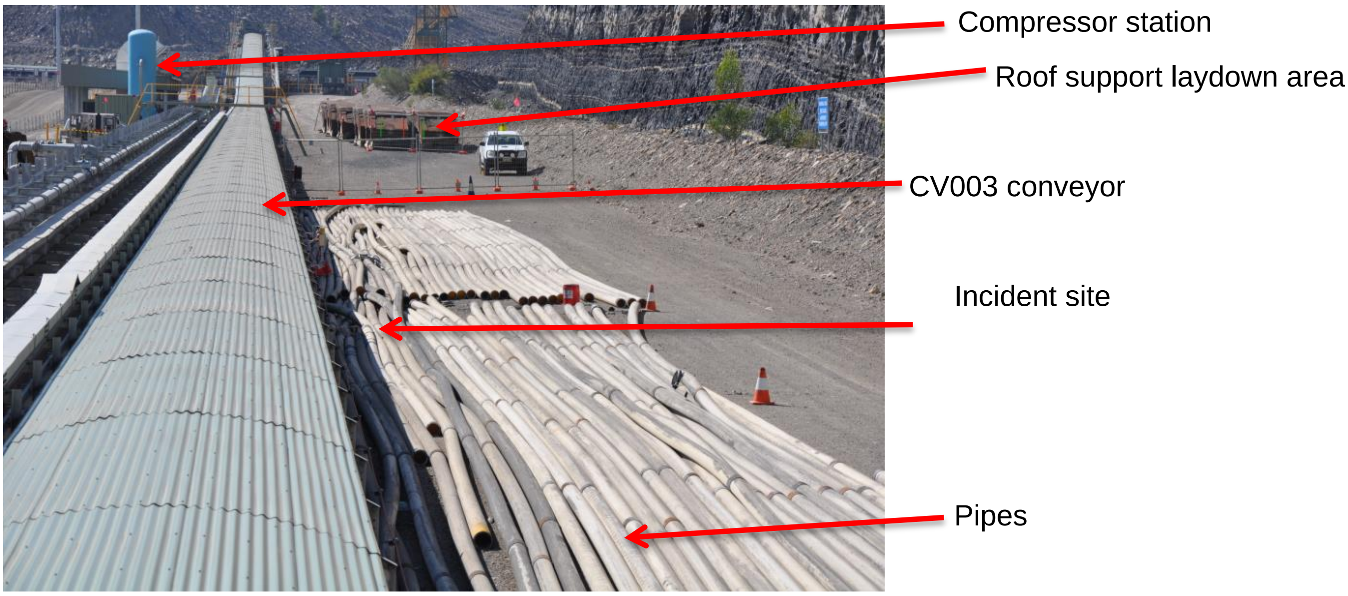

# 2. Incident overview

## 2.1. Description of the circumstances of the incident

On 26 November 2015, a worker employed by Falcon Mining, a subsidiary of Mastermyne Pty Ltd (Mastermyne) suffered serious leg injuries while pressurised leak testing a 160 mm diameter polypropylene inert pipe line on the surface at Ulan West Mine, Ulan Rd, Ulan, NSW.

The worker, along with other workers were relocating, inspecting and testing 52 x 160 mm diameter polypropylene inert gas pipes that were recovered from the underground workings of Ulan West Mine.

Figure 3 – Photo showing the pipeline lay down area adjacent to conveyor CV 003.



The 160 mm diameter polypropylene inert pipeline was erected in the travelling roads of the developing longwall blocks. The pipeline remained in place and was removed as the longwall began to retreat.

The purpose of the inert pipeline was to provide a means of injecting nitrogen gas into the goaf area behind the retreating longwall block to suppress any spontaneous combustion of the coal if detected.

Two days before the incident, the worker and his colleagues were tasked with the relocation of 52 pipe assemblies that were stored alongside conveyor CV003, in an area that was set aside for the storage of longwall roof supports (chocks).

Using a load haul dump (LHD) machine, the worker and a colleague moved the pipes about 50 m closer to the ‘A’ heading entry of the mine (inbye), alongside conveyor CV003. The process used to move the pipes was in accordance with the mine’s procedure, *Installation and removal of inert pipeline service ranges roadways*.

On 25 November 2015 the worker and his colleague were physically inspecting and pressure leak testing each pipe assembly in accordance with the mine’s procedure. At the completion of the first shift, about 25 pipe assemblies were successfully pressure leak tested and recorded as being fit for reuse.

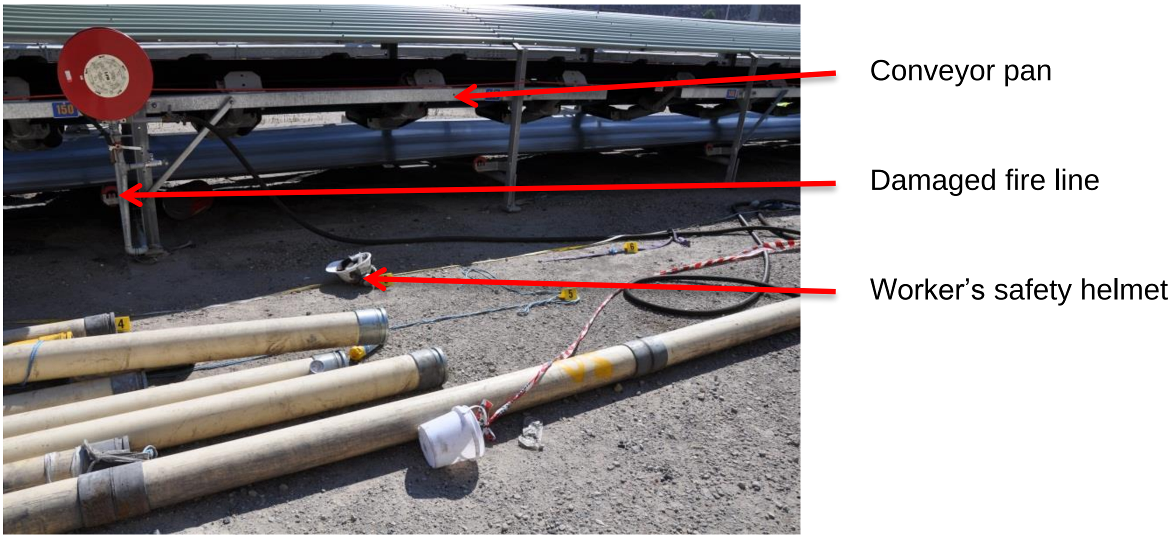
On 26 November 2015 the worker and his colleagues were preparing to complete the remainder of the pipe inspections. At 10.15 pm, the workers had coupled up the last pipe, identified as pipe 52, and began to pressure leak test it.

Pressure leak testing required the pipe assemblies to be prepared at both ends by coupling up a pressure gauge manifold at one end of the pipe and a pressure manifold at the other end. Compressed air was then introduced from the mine’s reticulating compressed air circuit to a pressure of 870 kPa by opening a manual valve on the pressure manifold (refer to Figure 1).
When the pressure reached that of the mine’s reticulated compressed air circuit of 870 kPa, the manual isolation valve was closed on the pressure manifold and the pressure leak test began.

The pressure leak test monitored the drop in air pressure (leak) over a specific time taken, with a pass/fail criteria being recorded.

Figure 4 shows the incident area between 149 pan and 150 pan of CV003 conveyor. The photograph also includes shows personal items belonging to the injured worker.

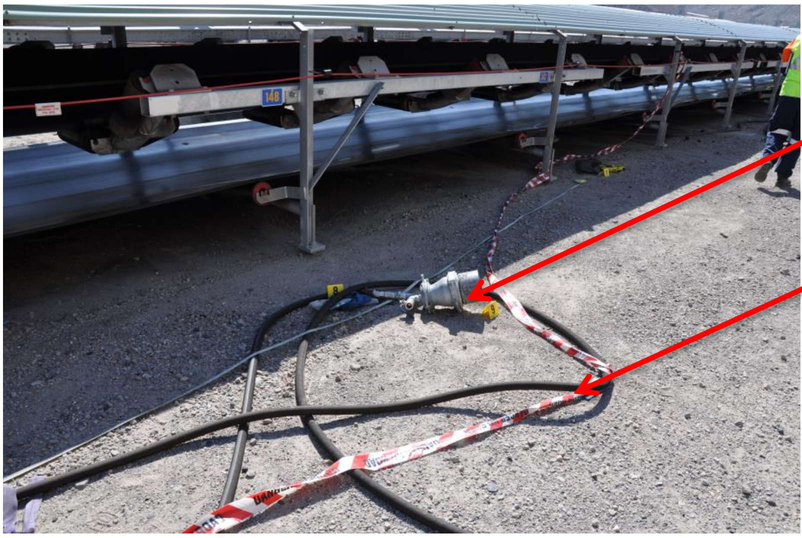
**Figure 4 – Photo of incident area adjacent to CV003 conveyor.**



Pipe 52 suddenly failed when the air pressure reached approximately 650 kPa on the gauge manifold. The pressure manifold suddenly separated from the end of the pipe with sufficient force and velocity to knock one of the workers to the ground. The worker was hospitalised with serious leg injuries.

The pressure manifold pipe end complete with the pipe swaged end was found about 6 metres from the pipe end (refer to figure 5).

**Figure 5 - Incident scene adjacent to conveyor CV003 at pan 148.**




The worker received initial treatment under the mine’s emergency management plan with emergency services called to the scene. He was then conveyed to Dubbo Hospital for emergency treatment and surgery.

Workers in the immediate vicinity were offered first aid treatment until the arrival of the mine’s emergency management team.

A 1” fire hydrant line at CV003 pan 150 was also damaged. Marks on the pipe and damage to a screwed joint were evidence of it being hit by a solid object and with sufficient force to fracture a threaded joint. This, in turn, released pressurised water into the working environment.

The mine reported the incident to the regulator. A mechanical inspector attended the mine on 30 November 2015 and issued a prohibition notice preventing any further testing on nitrogen pipeline using compressed air from the mine’s reticulated compressed air. A scene assessment was subsequently undertaken by inspectors on 15 December 2015.

The fire hydrant at 150 pan on CV003 was marked from an impacting object (refer to figure 6).

**Figure 6 – Damaged fire hydrant at pan 150 CV003 conveyor.**


## 2.2. Injuries to the worker

The worker's injuries included:

- broken nose, not requiring surgery
- broken left little finger, requiring surgery to insert a wire support
- both right and left arms were peppered (sandblasted) with small rocks from the escaping compressed air from the separated pie end
- ligament damage to this right knee, requiring surgery
- cartilage damage to this right knee, requiring surgery
- fracture of this right fibula bone, not requiring surgery.

The worker was also treated with twice-weekly physiotherapy and eventually a return to work program. He returned to work on alternate (light) duties on 20 April 2016.

### 2.2.1. The worker's industry experience

The worker involved in the incident was a shift supervisor and mine worker with five years' experience. His general mining experiences included moving belts, installing ventilation devices, e.g. stoppings, overcasts at Ulan West and he spent time at Ulan #3 mine. He had no specific training or experience with pressure leak testing of pipelines other than generic mine training.

## 2.3. Inspectors' observations on 15 December 2015

On 15 December 2015, the inspector of mechanical engineering attended Ulan mine and saw that, on arrival to the incident site, the area was barricaded off using temporary fencing. About 50 pipes of about 50 m in length were inside the compounded area where the incident occurred.

Pipes were laid out side by side in close proximity to conveyor CV003.

a) Figure 4 shows how closely workers were positioned to CV003. It was reportedly running at the time of the incident.

b) There were areas where pipes were packed on top of each other, creating potential trip hazards.

c) Pipes were undergoing both a visual and leak test to determine if the pipes were able to be reused after being recovered from Main-gate 1 roadway.

d) All pipes being tested were being identified by an item number painted onto each pipe with the results being recorded on a sheet for further reference.

e) The incident pipe was identified as pipe # 52, which was the number painted on the pipe by the injured worker. Pipe #52 was entered as exhibit 2 according to the chain of custody report. For the purpose of the investigation this is identified as exhibit #2.

f) Pipe #52 was about 50 m long and made up of 5 x 10 m length pipes swaged together using swaged joiners.

g) Pipe #52 had, at the inbye end, a pressure gauge manifold fitted for recording maximum pressure and leakage pressure.

h) Pipe #52 had, at the opposite end where the incident occurred, a pressure manifold fitted. This consisted of a series of isolation and bleed valves coupled to a 1" air hose that was connected to the mine's reticulated air supply.

i) Compressed air was supplied from a surface compressor station in the box cut about 50 m outbye of the incident scene and on the opposite side of conveyor CV003 (refer to figure 3).

j) The surface compressor station reticulated compressed air into the mine's workings via a solid steel pipe line along the main and longwall gate roadways.

k) The surface compressor station comprised of four Sullair air compressors connected in parallel into the mine's reticulated airline.

l) The mine's reticulated air supply was operating at a pressure of about 870 kPa at the time of scene assessment. Refer to figure 8 for digital readouts for pressure, temperature and current load

m) The system air pressure reading was taken from the surface compressor station on pressure recording devices.

n) After the pressure manifold on pipe #52 had separated from the pipe end, both pressure manifold and pipe # 52 were found to be about 6 m apart.

o) The shouldered end of the incident pipe had separated from the end of the polypropylene pipe (refer to figure 9).

**Figure 7- Control panel for Sullair compressor**


**Figure 8 – Incident pipe end**


p) The pressure manifold was found still attached to the 1” flexible supply airline.

q) The 1” flexible airline was still connected to the mine’s reticulated air supply, with the isolation valve in the closed position.

r) The incident scene was scattered with a number of items. These included a safety helmet, safety boot and hand tools, towing slings, blue rope, pipe fittings and a pressure gauge.

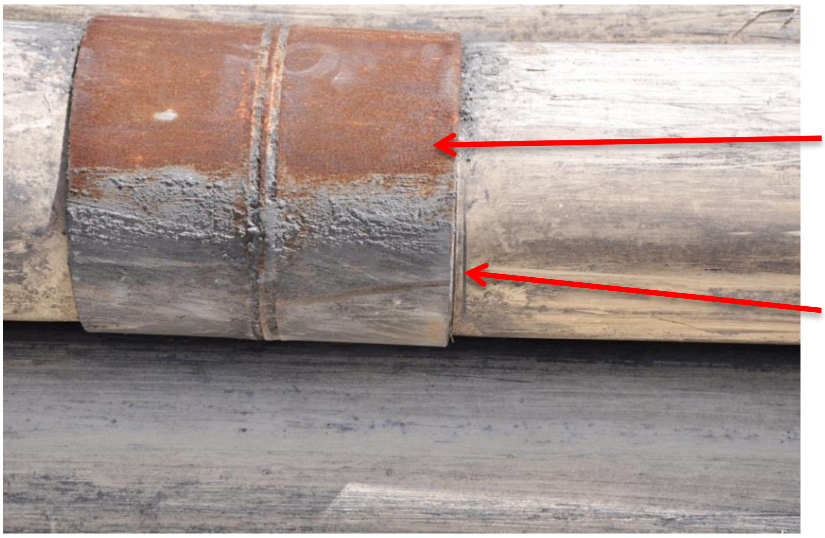
s) The pipes were in the laydown area where they were undergoing inspection and testing. A number of pipes had been identified as non-serviceable because of physical damage.

t) Most of the pipes in the laydown area showed signs of heavy marking, scratches and gouges to the outer FRAS covering that was attributed to the installation and recovery process. Pipes were dragged to and from MG1-TG2 roadway using load haul dump machines.

u) A number of swaged joiners showed evidence of wear and corrosion possibly from the transportation and/or recovery process (refer to figure 10). A swaged pipe joiner is used to couple multiple pipes together to form one long pipe assembly.

v) Some of the joiners showed evidence of movement, possibly caused by acute bending during the transportation and recovery process.

Figure 9 - Swaged pipe joiner




# 2.4. Information provided by witnesses

The investigation found:

a) A work authorisation permit was completed by the Mastermyne's supervisor for the relocation and pressure testing of the inert pipes.

b) A work procedure was provided by the task supervisor for Ulan West, which contained procedures for towing and leak testing of pipes using compressed air.

c) A 'Take 5 'personal risk assessment was undertaken by the injured worker and his colleague on the day before the incident. The Take 5 did not consider:

   i. the sudden failure of the pipe or pipe-fitting connection

   ii. working in close proximity to a moving conveyor.

d) The Mastermyne workers involved in the pressure leak testing of the pipe had no experience with the process nor were they provided with any training before starting the task. For those involved, this was there first time they had undertaken the task of pressure leak testing inert polypropylene pipes.

e) Work authorisations were only previously issued to contractors of Ulan West Operations for undertaking work at the mine. No work authorisations were issued to permanent employees for undertaking the same work as the contractor. The recovery of the pipeline from MG1_TG2 had been carried out by permanent employees of UWO and not contractors.

f) On the day of the incident, the pipe pressure leak testing task coordinator for Ulan had returned to work on the dayshift to discover that the signed work authorisations for relocating the recovered pipeline now included the pressure leak testing of the recovered pipes.

g) The task coordinator identified some discrepancy with the pressure leak testing procedure but he did not stop the work from proceeding until a review of the procedure had taken place.

# 3. Pipe/fitting connection failure

## 3.1. Designer - CalAir Systems Pty Ltd

CalAir Systems Pty Ltd (CalAir) is a company that designs, manufactures and supplies non-metallic pipes to a number of industries including the air conditioning, firefighting and waste water collection industry.

CalAir, through its research and development company Cumbrae Pty Ltd (Cumbrae), designed and developed a range of non-metallic pipes with fire resistant anti-static properties for the Australian coal mining industry.

CalAir systems and UGM Mining Solutions formed a company called Pipelion Pty Ltd (Pipelion) for the purpose of using the Cumbrae intellectual property and technical expertise to develop and manufacture FRAS non-metallic pipes for the Australian coal mining industry. The partnership with UGM Mining Solutions would provide a manufacturing and distribution licence to market the Pipelion products.

Pipelion produces three products for the coal mining industry that are colour coded for their particular application. They are:

- red pipe for fire suppression systems
- blue pipe for compressed air systems
- violet pipe for waste water pumping systems.

### 3.1.1. Pipe not designed by CalAir Systems

The investigation found that the sample of the inert pipe (beige) provided to CalAir systems from UGM Mining Solutions did not meet the manufacturing requirements of the Pipelion R&D Plan version 1.2.

According to the designer from CalAir Systems, the pipe had a number of manufacturing defects and abnormalities that were outside the requirements of the Pipelion R&D Plan. The designer from CalAir Systems recommended this product not be manufactured.

## 3.2. Manufacturer and supplier

UGM Mining Solutions entered into a manufacturing and distribution agreement with Pipelion to manufacture and distribute non-metallic pipes into the Australian coal mining industry.

A small research and development plant was established at the UGM’s Teralba facility for the purpose of industrialising Cumbrae’s intellectual property and technical expertise to manufacture FRAS non-metallic pipes.

The Pipelion product line included:

- a red pipe (160 mm diameter rated at 2100 kPa SWP) for firefighting supply lines
- a blue pipe (160 mm diameter rated at 1000 kPa SWP) for compressed air supply lines
- a violet pipe (160 mm diameter, rated at 2100 kPa SWP) for waste water pumping lines.

At a later stage, a fourth product was introduced to the product line:

- a beige pipe (160mm diameter, rated at 1000 kPa SWP) for delivering inert gas into the underground workings of a coal mine to aid in the suppression of a potential fire outbreak caused by spontaneous combustion of coal.

# 3.3. Testing of beige incident pipes and fittings

## 3.3.1. General overview

A series of tests on the incident pipes were undertaken at the Teralba factory.

Testing included the measurement and visual inspection of the pipes. A series of pipe test samples were made from the exhibits 10 and 11[1] as well as newly manufactured pipe. These sample pipes were subjected to:

- visual and dimensional checks
- proof pressure testing
- tensile testing to destruction.

Newly manufactured pipe was also subject to proof testing and pressure testing to destruction.

All results were recorded and provided in the test report from UGM Mining Solutions.

## 3.3.2. Test results/findings

Dimensional checks of the incident pipe identified the swaged pipe ends and pipe joiners were swaged to the original dimension of 170.5 mm.

It was noted that following the previous incident (refer to section 3.4.1) there was a recommendation to re-swage all fittings to the new dimension of 168.5 mm. This dimension was determined after exhaustive testing from the manufacturer/supplier into the separated joiner incident in February 2015. This reduced crimping was to compensate for the identified undersize pipe.

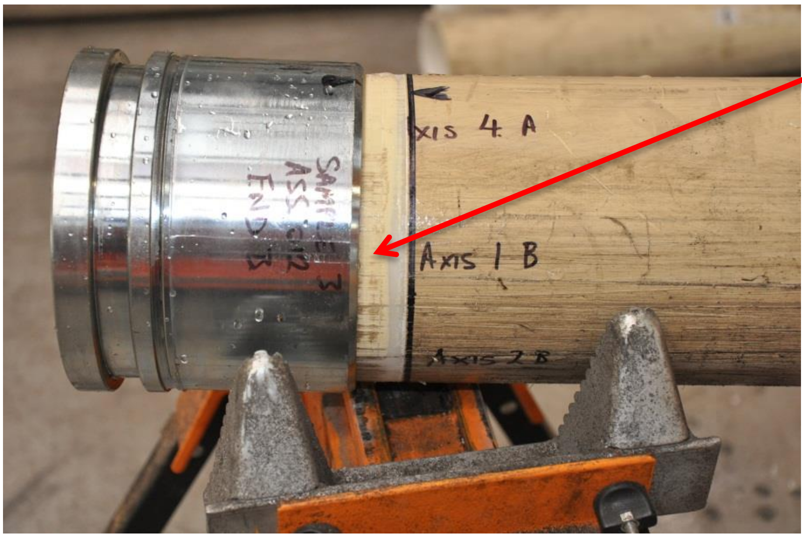
Pressure testing was carried to determine the integrity of the pipe and fitting assembly. From the test results, the sample pipes performed within expectations, with the exception of the test for pipe assembly ‘ass 012’ as shown in figure 10.

Pipe ass 012 was assembled from a section of incident pipe called exhibit 10 and was fitted with two ends swaged to a dimension of 170.5 mm. The purpose of this test was to try to replicate the failed incident pipe.

The swaged fitting began to move along the pipe at a pressure of 2500 kPa. This is 500 kPa below design expectations.

1 Exhibits 10 and 11 were pipe samples of approximately 3 m in length of the incident pipe (not including the  swaged end that failed, Refer to exhibit 2)

**Figure 10 – Ass 012 showing swaged end separation**

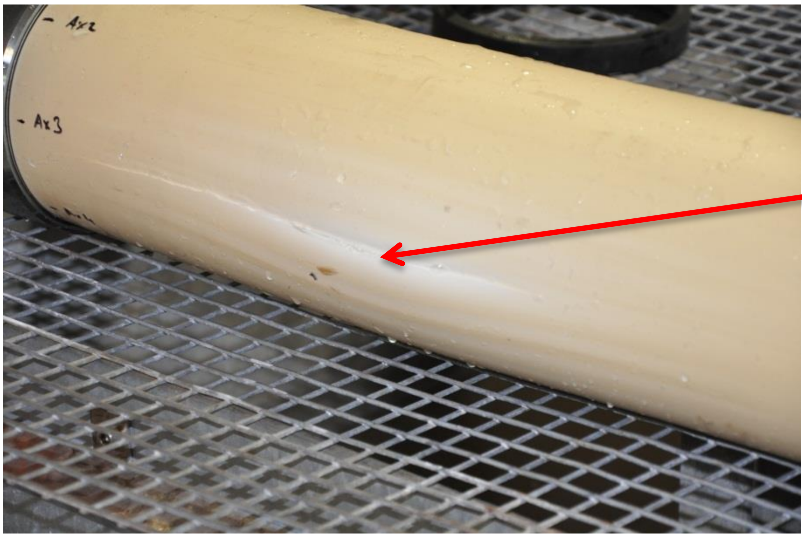



Swaged end has begun to separate from the polypropylene pipe during hydrostatic testing

A set of control pipes[2] were assembled from beige pipe manufactured to specification with pipe ends swaged to 170.5 mm. These control pipes were subjected to increasing pressure until ultimate failure. The control pipes failed as the designer intended, that is, the polypropylene pipe began to visually deform at approximately 2500 kPa with ultimate failure of the pipe at 3000 kPa.

These tests were recorded using a GoPro camera that clearly shows the pipe failing. The pipe material progressively failed without swaged end separation (refer to figure 12).

**Figure 11 – Control pipe tested to failure.**



Failure point of pipe material

The control pipe testing supports the original designer's assertion that the pipe material would fail gradually with no pipe end separation, providing the pipes were manufactured and assembled in accordance with the original designer's specifications.

[2] Control pipe being a pipe assembly that is manufactured to the correct design specification

### 3.3.3. Summary or testing

This testing indicates that

a) The undersize incident pipe, when crimped to the original design specification of 170.5 mm resulted in failure, with the pipe swaged fitting coming off the end of the pipe.

b) A pipe manufactured to design specifications would fail by plastic deformation of the pipe with the swaged fitting remaining intact.

### 3.3.4. Manufacturer's conclusions

Based on the test results in 3.3.2 above, the UGM Mining Solutions test report examined a number of possible causes for the failed joint (pipe #52, exhibit 2). These include:

a) The towing method was determined to have been the most likely and major contributing factor to the failure because:

   i. the failure occurred on an end coupling

   ii. the aforementioned end coupling was connected to the LHD

   iii. there was no control on the quantity of pipes connected to the end coupling acting as the towing connection

   iv. the combination of load and impact (caused by intermittent resistance with varying ground conditions) could result in 'spikes' in tension loading at the end coupling

   v. bending at the end coupling, especially under load and impact, can cause separation between pipe end and coupling.

Destructive tests showed joints to be sound and failure would only occur if subjected to 'longitudinal forces' greater than 3 tonne. The tractive effort of modern LHDs exceeds 7 tonne. In the absence of suitably rated and flexible towing attachments, damage will occur.

The methods of onsite testing, while not a contributing factor to the failure, need to address the obvious risk associated with the test procedure and potential outcomes. They should also accommodate specific issues associated with towing that may contribute to a reduction in the integrity of the swaged joint. It was noted a deep impression was on the back of the pipe where the swaged coupling would normally be located, refer to figure 13.

**Figure 12 – Pipe #52 (exhibit 2) being checked**

Deep impression where the back of the swaged fitting was pushed into the polypropylene pipe from an undetermined mechanical force.

### 3.3.5. Manufactured pipe size

The investigation also found:

a) According to the Pipelion R&D plan version 1.2, the finished size of the pipe was required to be 160.00 mm to 160.50 mm.

b) Production records show one pipe every hour was being dimensionally checked, with approximately 7 to 10 pipes per hour being manufactured in any given shift.

c) Production records did not provide any detail on where or how the dimensional checking was being undertaken.

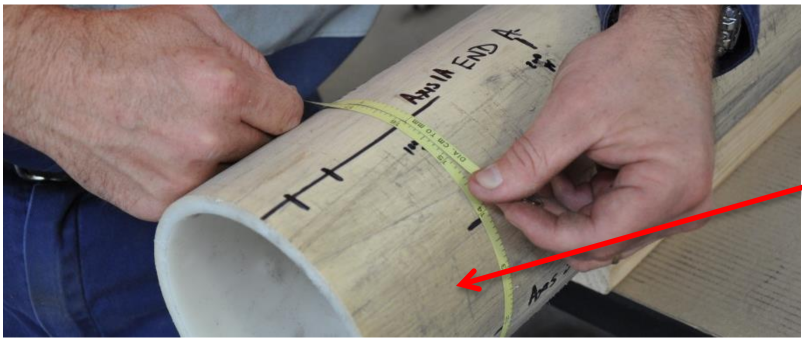
d) Production records dated 26 March 2014 showed 616 metres of pipe manufactured with no outside dimensional checks taken throughout the 10-hour shift.

e) Production records dated 31 March 2014 showed 226 metres of pipe manufactured with the first dimensional check of one pipe at the fourth hour of the 10-hour shift.

f) From the production records provided by UGM from 25 March 2014 through to 31 March 2014 and 2 April 2014 through to 8 April 2014, pipes were on average being dimensionally checked at a rate of one pipe every hour. Those pipes recorded dimensions within specification in accordance with the Pipelion R&D Plan version 1.2.

g) The method for measuring the critical dimensions of outside diameter, ovality and wall thickness may not have been performed in accordance with the Pipelion R&D plan version 1.2. The R&D plan version 1.2 required outside dimensions to be measured using outside micrometres in four places and the wall thickness measured using Vernier callipers. During sample testing on 5 April 2016, 6 April 2016, 20 May 2016 and 13 July 2016, it was identified that UGM Mining Solutions was measuring the pipes outside diameter and ovality with a non-calibrated, non-graduated circumference (Pi) tape (refer to figure 13).

**Figure 13 – Pipe diameter measurement**



Circumference (Pi) tape measure, non-calibrated and non-graduated.

## 3.4. Previous incidents on similar pipes

### 3.4.1. Ulan mine, February 2015

On 25 February 2015, an inert pipe line was being commissioned underground in main gate 2 using the mine’s compressed air supply, when a swaged joiner separated from the pipe end, allowing compressed air to escape into the working environment.

Ulan West and UGM Mining Solutions, completed an investigation to determine causal factors that led to the incident.

Ulan West's Incident Causation Analysis Method (ICAM) investigation report made the following comments and recommendations:

a) The SWP identified an unplanned release as a major hazard but no controls identified.

b) The SWP did not make reference to any barricades or demarcated work areas for the testing process.

c) Consider the implementation of a pressure relief valve.

d) The SWP did not identify the pressure required to charge the pipe lines for the required testing.

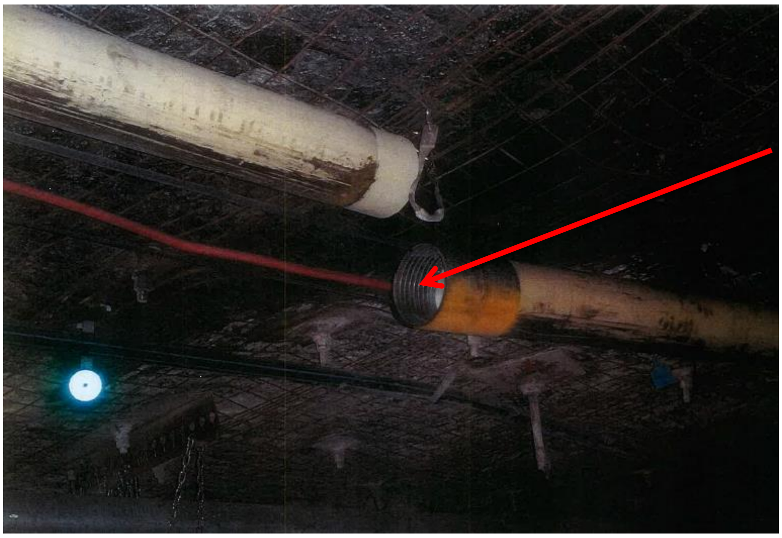
e) Consideration should be given to best practice methods for the detection of leaks in pipelines i.e. use of soapy water to look for bubbles.

f) Comments from the Ulan West mechanical engineering manager on 10 March 2015 as to trials conducted at the mine by UGM Mining Solutions with identified:

- changes to the crimping dimension on the pipe swaging machine
- rechecking the pass/fail criteria to the swaged fitting
- changes to the pipe towing requirements.

In February 2015, after being leak pressure tested with compressed air, a swaged joiner separated (refer to figure 14).

**Figure 14 – Swaged joiner separation.**



Swaged joiner separated from polypropylene pipe end

## 3.4.2. Investigation outcomes not implemented

The following recommendations (refer to section 3.4.1) were not acted upon at the time of the incident.

a) The revised SWP dated 12 November 2015 did not include:

   i. the use of barricades or demarcated areas

   ii. the use of a pressure relief valve

iii. consideration for alternatives to leak testing with compressed air.

b) Changes to the method of towing (refer to figure 16). This was not the recommended procedure for the recovery and towing of polypropylene pipes.

c) Recommendations that all previously swaged pipe ends would need to be re-swaged to a new revised dimension of 168.5 mm.

Not all pipe ends of 170.5 mm underwent the recommended rework. The incident #52 had the pipe ends swaged to the initial dimensions of 170.5 mm and was not part of the rework batch as recommended by the supplier.

d) It appears the outcomes from the February 2015 investigation were not provided to Mastermyne by the mine. This information would have assisted in undertaking an effective risk review before the start of the pressurised leak testing by Mastermyne (refer to section 3.4.1).

**Figure 15 – Recovered poly pipes towed out of the mine.**

Stainless steel tether straps are designed to support the pipe line when being suspended from the mine's roof support structure.

## 3.5. Other incidents

There has been one other reportable incident at another underground coal mine when a pipe coupling separated from the polypropylene pipe during pressurised leak testing.

# 4. 'Pressurised leak' testing of pipes at the mine

## 4.1. Mine operator

From the investigation, the following is a typical sequence cycle for the use of polypropylene inert pipe lines:

a) Pipes without swaged coupling ends are provided in 10 m lengths to the mine.

b) Multiple lengths of pipe are joined together into pipe assemblies of approximately 50 m in length using swaged joiners and swaged shouldered ends.

c) Pipe assemblies are pressure leak tested using the mine's compressed air supply of 870kPa before being dragged underground.

d) The assemblies, (three at a time) are dragged underground behind an LHD into the installation area.

e) The assemblies are then installed to the roof using an LHD and modified work basket. The work basket is fitted with rollers to help in the lifting process as the LHD moves forward.

f) The assemblies are retested for leaks every 100 m after being installed with the aid of the mine's compressed air supply of 870kPa.

g) The assemblies remain installed in the required roadway until they are no longer required.

h) The assemblies are recovered in 50 m lengths and dragged using an LHD back to the surface and stored for reuse.

i) The assemblies are inspected and leak tested in readiness for reinstallation underground.

## 4.2. Contractor – Mastermyne Pty Ltd

Mastermyne is a company that has a contract with Ulan West Operations through the technical services department to provide work installing ventilation appliances. Their work includes the installation of ventilation regulators, trap doors, permanent stoppings and other associated work. All work is directed and coordinated by the mine's ventilation officer.

The mine ventilation officer gave Mastermyne the task of undertaking visual inspections and pressurised leak testing of recovered inert pipes that were in the box cut adjacent to CV003 conveyor.

A joint inspection was undertaken by the mine's ventilation officer and Mastermyne's site supervisor to understand the scope of work. This included the

- relocation of the stored pipe assemblies that were about 50 m towards (inbye) the mine's portal entry 1, and
- the physical inspection and pressure leak testing of the pipe assemblies.

Results were then to be recorded on a sheet provided with each identified pipe assembly logged as either 'pipe damaged' or 'okay'.

The mine manager of mechanical engineering was not involved with this task.

## 4.3. Designer information CalAir Systems

In relation to pressurised 'leak' testing, the designer of the pipe, CalAir Systems stated:

a) Pressurised testing needs to be done using a non-compressible medium like water.

b) To use compressed air on pipes not being manufactured in accordance with the sizes laid out in the R&D program was a concern.

c) CalAir Systems would hydrostatically test with water as compressed air was considered higher risk from sudden energy release.

d) The three pipes approved for manufacture by Pipelion, those being airline (blue), fire line (red) and mine water (violet), were all originally design tested by the use of pressurised water as CalAir was aware of the dangers when using compressed air for testing.

e) Test pressures to reach ultimate failure of a pipe could be as high as 3000 kPa for the blue pipe and even higher for the red and violet pipe as they had higher working pressures.

f) The working pressures approved by CalAir for the respective pipes were 900kPa (blue pipe) and 1800kPa (red and violet pipe), however, the Pipelion products now displayed a working pressures of 1000kPa and 2200kPa respectively without approval from the designer CalAir Systems.

g) It was not the designer of the beige pipe.

## 4.4. Manufacturer and supplier information

Information from the manufacturer and supplier of the beige pipe (UGM Mining Solutions) included a safe work method statement (UGM SWMS V3). This SWMS provided an eight-step procedure on the pressure leak testing of swaged polypropylene pipe using compressed air.

However, the SWMS did not:

a) identify the need for barricades or demarcation zones during the testing process

b) consider a sudden release of fluid under pressure during leak testing as an unwanted event from either:

   i. the bursting of the polypropylene pipe, or

   ii. the separation of the swaged ends from the polypropylene pipe and

c) provide for risk prevention measures for an unwanted event, i.e. the sudden release of fluid under pressure.

### 4.4.1. Design risk assessment

UGM undertook a design risk assessment for Pipelion FRAS rated non-metallic pipe, dated 15 September 2015, which considered joint and end failures due to incorrect design of:

a) pipe (size).

b) end and joiner (size)

c) interferences of fit

d) swaging machine

e) swaging procedure.

With a risk ranked outcome of:

a) category group = ‘H’ for hazard

b) consequence type = ‘P’ for people

The design risk assessment for Pipelion FRAS rated non-metallic pipe provided for the following risk control measures for the above identified hazards/issues:

a) known standards

b) designed to Australian Standards

c) designed to engineering standards

d) design audit by third party

e) testing regime

f) inspection regime.

These control measures are too general and do not provide clear information on how the identified hazards are being controlled.

# 4.5. Site system of work

## 4.5.1. Contractor work authorisations

The mine employed a generic process of 'work authorisation' for use by contractors when undertaking any work assigned to a contract group by a task coordinator from Ulan West. The document was completed by the contractor before the work could begin.

The document was comprehensive and had provision for:

a) job details including:
   i. name of person completing the form
   ii. the company/contractor assigned to do the work
   iii. location of work
   iv. equipment required to complete the work
   v. job description
   vi. expected duration
   vii. name of the Ulan West Operation's task coordinator authorising the work.

b) pre-job inspections

c) any specific work permits to be issued

d) SWP or SWMS identification to be recorded for the work, including document number

e) identification of hazard controls from selected list

f) a pre-job start list from a selected group of drafted questions

g) the recording of task inspections from Ulan personnel

h) the recording of work area at the completion of the work from a selected list

i) a sign off for job completion/cancellation from both the contracting company and Ulan task coordinator

j) the development of a specific safe work method statement if none are available

k) all personnel involved in the work to be entered onto the document with a provision for acceptance of all documents attached to the work authorisation form

l) the Ulan task coordinator to certify the work authorisation has been reviewed and completed so the work can begin

m) an emergency plan.

A contractor work authorisation was completed by the contractor's supervisor for the task of leak testing the polypropylene pipe and authorised by the Ulan West task coordinator.

## 4.5.2. Safe work procedure (SWP)

The mine developed a SWP (ULW TS PRO 0061, dated 7 April 2014) for the *Installation of inert pipeline service ranges in underground roadways*. This document was approved by the technical services manager, with the document owner being the mine's ventilation officer.

Document ULW TS PRO 0144 was developed by the ventilation officer following a review of document ULW TS PRO 0061, which was superseded. Document ULW TS PRO 0144 was titled *Installation and removal of inert gas pipeline service ranges roadways*, dated 12 November 2015 and approved by the technical services manager. Document ownership was retained by the mine's ventilation officer. This document was approved for use 14 days before the worker was injured on 26 November 2015.

The document ULW TS PRO 0144 is divided into seven sections:

a) 1.0 Purpose.

b) 2.0 Major hazards.

c) 3.0 Equipment requirement (general).

d) 4.0 Equipment requirements (specific).

e) 5.0 Change information.

f) Appendix A – installation standard.

g) Appendix B – pressure testing record sheet.

Section 4 comprised job steps, hazards and controls. Workers were required to "visually and pressure check installed 100m section of pipe".

The document identifies hazards as:

i. Less than adequate (LTA) isolation and

ii. Stored pressure.

Controls identified in the document are:

i. Isolate 100 m section of inert pipeline by closing gate valves on both ends of section.

ii. Attach "inert gas line test" end cap to T-piece.

iii. Attach a 1" airline and pressure gauge to end cap.

iv. Open gate valve on T-piece.

v. Charge pipeline with air and take reading – record on sheet provided in Appendix B.

vi. Leave for 15 minutes and take second reading – record result.

vii. Once reading has been taken, isolate bleed pressure and remove airline from end cap.

viii. Close gate valve on T-piece.

ix. Open gate valve located at each end of the section of pipeline that was tested.

x. Provide pressure reading to ventilation officer at end of shift.

xi. Safety clips to be installed on all hoses.

The above SWP, ULW TS PRO 0144 document was provided as part of the work authority package to contract workers tasked with undertaking the leak testing of the pipes.

The outcomes from the previous incident dated 25 February 2015 were not provided to the contract workers, so they were unaware of any findings or recommendations from Ulan West's incident investigation.

The SWP provided to the contract workers, although recently revised, also did not include the findings and recommendations from the accident investigation report.'

## 4.5.3. Risk assessment

A formal risk assessment was not provided to the contract workers other than the safe work procedure. The existing SWP did not fully address all hazards associated with the life cycle of the pipe from initial installation, pressurised leak testing, recovery, reverification, pressurised leak testing and reinstallation in a new area of the mine.

## 4.5.4. Task inspections

The following is a timeline of events before the start of the inspection and leak testing:

a) On 23 November 2015, the contractor's supervisor and the Ulan West ventilation officer visited the work site where the polypropylene pipes were being stored, adjacent to the CV003 conveyor.

   The following was undertaken:

   i. The purpose of the inspection was to become familiar with the task and to discuss any specific requirements, which included the numbering of the pipes, their condition and whether they were fit (that is, okay) to reuse or whether they were unserviceable. All results were then to be recorded on a record sheet provided.

   ii. The site inspection identified the pipes were being stored in an area that was allocated to the storage of roof supports in preparation for the next longwall move and required relocation.

   iii. A new storage area for the pipes was identified. This required the pipes to be dragged about 20 m inbye (towards portal entry 1) of the mine before the visual inspection and leak testing could begin.

b) On Monday, 23 November 2015 and Tuesday, 24 November 2015, the injured worker and a colleague moved about 50 pipes to the new work area previously identified by the Ulan West ventilation officer.

c) On Wednesday, 25 November 2015, the two workers met the contractor's supervisor to discuss the testing equipment before any testing began.

d) At 10.06pm, an outbye deputy undertook an inspection of the worksite and signed off on the work authorisation form to say all paperwork was in order. At the time of this inspection, the two workers were having a meal break.

e) According to the work authorisation dated 24 November 2015 for this task, there were no other inspections recorded on the work authorisation form as being completed.

f) The incident occurred on Thursday, 26 November 2015.

## 4.5.5. Mine operator supervision

### 4.5.5.1. Engineering staff

At the time of the incident, the engineering structure at the mine consisted of the following:

a) All engineering work at the mine was controlled by the mine's engineering department. The head of the department was the engineering manager who reported directly to the mine general manager.

b) The statutory mechanical engineering manager reported directly to the engineering manager.

The investigation could not find evidence of the mechanical engineering manager being involved in the selection of the Pipelion product for use at Ulan West for goaf inertisation. The mechanical engineering manager, however, was involved in the incident investigation in February 2015 when a Pipelion swaged joiner separated during pressurised leak testing with compressed air. The mechanical engineering manager was not involved in the process of pressurised leak testing the Pipelion product on 26 November 2015.

The installation and commissioning of the inert pipeline was left to the mine's technical services department with the task coordination given to the mine's ventilation officer.

The investigation found there was little to no consultation between the mechanical engineering manager for the mine and the technical services department regarding the process of inspection and pressurised leak testing the polypropylene pipe.

Production schedules provided by the mine shows the role of recovery, testing, reinstallation and retesting was assigned to the ventilation officer who reported to the technical services manager for the mine.

#### 4.5.5.2. Ventilation officer

The ventilation officer role is a statutory ventilation role and the position reports directly to the technical services manager. The ventilation officer holds a qualification in ventilation from UNSW.

The role of the ventilation officer is to ensure appliances associated with the mine's ventilation are installed and maintained to the required standard. This includes the installation, commissioning and subsequent recovery of the Pipelion pipes from the mine workings.

The ventilation officer was a task coordinator and the authoriser of the work authorisations process. Work authorisations are completed by contractors before the start of any work at the mine.

The ventilation officer was the document originator and owner of the SWP used for the transportation and pressure leak testing of the Pipelion pipes.

## 4.6. Systems of work – contractor

### 4.6.1. System of work – pressure leak testing

From the documentation provided, the investigation found the following:

a) Before the work began on pressure leak testing the pipes, a work authority was raised by the Mastermyne supervisor.

b) The work authorisation pack provided to Mastermyne included a SWP.

c) The work authorisation pack (including SWP) was reviewed by those directly involved in undertaking the task of pressure leak testing the Pipelion pipes, with a sign off from those involved in the task including Mastermyne supervisor.

d) The task coordinator for Ulan West reviewed the work authorisation and signed off so the work could begin.

e) The work authorisation did not contain any reference to, or recommendations from, a similar incident in February 2015 where a separated swaged pipe joiner separated from the pipe end during pressurised leak testing with air.

f) Workers from Mastermyne were unaware of the February 2015 incident, which included recommendations and changes to the process of pressurised leak testing.

### 4.6.2. Supervision of task

a) The task coordinator for the mine reviewed and signed off the work authorisation form before the work began.

b) The overall supervision for the task once authorised was left to the Mastermyne supervisors.

c) A mine deputy inspected the worksite on 24 November 2015 at 10.06pm and signed off on the work authorisation.

d) No other mine supervisor inspected the site for the duration of the pressurised leak testing task.

### 4.6.3. Training of contractor employees

a) Workers of the contractor undertook the task of leak testing for the first time and had not received any training in this particular task of leak testing pipes.

b) Workers of the contractor applied a personal risk assessment on the day, a ‘Take 5’. This risk assessment did not recognise sudden failure of the pipe or the separation of swaged fittings as a potential risk.

c) Hazards identified on the ‘Take 5’ were:

   i. “pinch points.

   ii. personal protection equipment correct use.

   iii. compressed air, isolate correctly before removing hose.

   iv. bleed air before disconnecting.”

# 5. Recommendations

## 5.1. Integrity of swaged fitting to non-metallic pipe connection

a) Manufacturers of non-metallic pressure pipe (polypropylene pipe that is injection moulded or similar) should have robust quality control systems to ensure:

   i. defects in pipe critical tolerances are quickly identified (real time) in the manufacturing process to ensure out-of specification pipes are not placed in the field, e.g. parameters such as pipe outside dimension, pipe ovality, pipe wall thickness, pipe ends cut squarely

   ii. pipe is only supplied for use if that pipe is compliant to design tolerance specifications

   iii. a full battery of tests is carried out and endorsed by the designer, where changes are made raw material, formulation or the manufacturing process. This is to ensure the changes do not adversely affect pipe performance as intended by the designer.

b) Consideration should be given to only providing non-metallic pressure pipes with factory-swaged ends and not field-swaged ends or field swaged double couplings.

c) When an incident occurs and the designer manufacturer or supplier provides recommendations to prevent reoccurrence, those recommendations should be implemented.

d) The swaging of non-metallic pipe fittings should only be carried out on new pipe of correct tolerance. Used (second hand) pipe may not be dimensionally compatible with the swaged fittings.

## 5.2. Pressurised leak testing of non-metallic pressure pipe assemblies

a) A SWP in relation to non-metallic pressure pipe testing should:

   i. consider all hazards associated with pressurised leak testing, including a sudden failure

   ii. be representative of the actual task being carried out

   iii. be prepared in consultation with the manager of mechanical engineering.

b) The use of work authorisation/permits/SWPs should not be limited to contractors undertaking work at the mine.

c) Pressure leak testing of a non-metallic pressure pipe assembly at any time should only be carried out were absolutely necessary. When pressure leak testing is necessary, the use of a non-compressible medium should be considered.

d) Where an abnormality is identified with a procedure or process, every effort should be made to stop the process immediately until the abnormality has been rectified and the process or procedure is reauthorised.

e) The establishment of strict controls e.g. well-defined go-no-go areas, barricaded areas, the use of guarding and/or mechanical restraints, provision for remote activation of energy source and remote recording/monitoring of the pressure energy should be undertaken.

f) The person undertaking pressure leak testing of pipe assemblies that involves the use of a pressurised medium should be fully trained and made aware of all risks associated with the task. This will assist with the implementation of suitable safe guards to prevent injury in the event of sudden failures.

## 5.3. Handling of non-metallic pressure pipe

a) All duty holders of polypropylene type pipes should consider the full lifecycle of the pipe including:

   i. intended use

   ii. methods of transport

   iii. means to lift pipe assemblies to the mine roof

   iv. pressure leak testing methods

   v. means the swag pipe fittings and join pipes together in the field

   vi. the number of pipes intended to be joined during transport.

b) SWP in relation to the handling of non-metallic pressure pipe should

   i. be representative of the actual task being carried out

   ii. consider potential damage to the polypropylene pipe assembly during transportation throughout the mine, installation and recovery

   iii. be prepared in consultation with the manager of mechanical engineering.

c) Dragging of pipes should be avoided where possible as this can lead to joints being stressed and resulting in sudden failures when pipes are placed into service.

d) To reduce the influence of external forces being applied to the pipe and joiners, consideration should be given to providing pipe of a single length only without double couplings being fitted.

# 6. Appendix

## 6.1. Interpretation

| Term | Definition |
|---|---|
| Ulan West | Ulan West Operations Pty Ltd |
| MG1 | Maingate 1 roadway at Ulan West mine |
| Mastermyne | Mastermyne Pty Ltd |
| SWP | Safe work procedure *Installation and removal of inert gas pipeline services ranges roadways* (Doc # ULW TS PRO 0144) |
| swaged fittings | Shoulder ends and double couplings swaged onto the non-metallic pressure pipe |
| non-metallic pressure pipe | Polypropylene pipe that is injection moulded or similar |
| LHD | Load haul dump vehicle |
| FRAS | Fire resistant and anti-static |