Inertisation of Loveridge No.22 Coal Mine

By

Queensland Mines Rescue Service

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LOVERIDGE NO.22 COAL MINE

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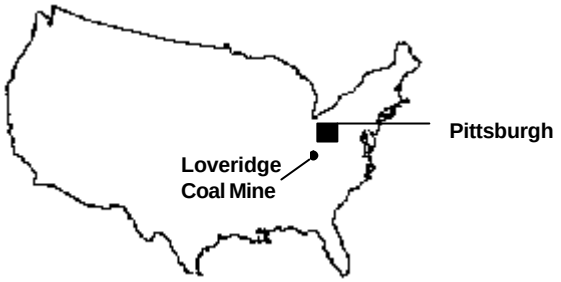
INTRODUCTION

In late February 2003 the Queensland Mines Rescue Service was contacted by Consol Energy Inc. regarding the possibility of using the GAG jet engine in order to inertise their Loveridge No.22 Mine which had been involved in an underground fire since 15th February 2003.
The mine is located near Fairview, West Virginia, which is approximately 135km south-west of Pittsburgh, Pennsylvania in the United States of America (see Figure 1).

FIGURE 1: Location Map



The fire started during the middle of the afternoon shift on Friday 13th February 2003. Coal cars loaded with garbage gathered from the operating sections and throughout the mine were brought to the slope bottom in order to be sent out of the mine for dumping.
One of the cars caught fire. The fire was thought to have been extinguished, using several fire extinguishers. Within a short time the fire had flared up again. The decision was made to pull the cars out of the mine to the surface via the slope track.
Whilst undertaking this task several adverse events took place that prevented the cars from being sent out via the slope track. The fire then spread from car to car and subsequently out of control.
Due to its gassy nature, the mine was evacuated and the shafts, boreholes and portal were sealed. Whilst these tasks were being undertaken water was being dumped down the slope. A total of six boreholes were drilled to use as mine atmosphere monitoring locations and to facilitate visual monitoring of mine conditions through a borehole camera.
The Loveridge Mine had a previous fire underground in June 1999, when miners were safely evacuated and the mine was sealed. Some 13 months later In July 2000, under a plan approved by the Mine Safety and Health Administration, mine examination teams re-entered the mine.
The mine was idle from August 2001 to December 2002, when it was re-opened.
In January 2003 limited mine development started with four continuous miners. A longwall was planned to be installed towards the end of 2003.
Consol has had to stand down some 297 employees and, by using the GAG jet engine to inertise the mine, they plan to recover the mine in a fraction of the time that it would normally take for the fire to burn itself out (up to 12 months or more in some cases).
Consol Energy Inc. is the largest producer of high bituminous coal in the USA, and the largest exporter of US coal. It has 20 bituminous coal mining complexes in seven states and one in Australia. In addition the company is one of the largest producers of coal bed methane, with daily gas production of approximately 135 million cubic feet. The company also produces electricity from coal bed methane at a joint venture generating facility in Virginia. Consol Energy's Research and Development Department located in Library, Pa and Morgantown, W.Va is the largest private research organisation in the US devoted exclusively to coal.

HISTORY OF INERTISATION IN THE QUEENSLAND MINES RESCUE SERVICE (QMRS)

The history of inertisation in the QMRS originated from recommendations made by the Warden's Inquiry into the accident at Moura No.2 underground mine on Sunday 7th August 1994.
A summary of these recommendations is as follows:

- That research is undertaken in order to determine the most appropriate method of inertisation for Queensland coalmines.
- Funds to be made available through the Queensland Government for such a system with appropriately trained people and operating systems. The inertisation system must be readily available, maintained and operated by the Queensland Mines Rescue Service on a fee for service basis.

- The successful trials of the jet engine determined the purchase of two GAG units plus the ability to operate both units if required, simultaneously.
- The GAG units were purchased in early 1998 at a cost of $1.3 million and handed over to the QMRS for operation and maintenance.

QMRS BACKGROUND INFORMATION

In 1996 the Queensland State Government announced that it was going to withdraw from the funding of mines rescue. It was subsequently agreed that the coal mining industry would assume sole responsibility for both the management and funding of mines rescue.
A public company, Queensland Mines Rescue Service Limited, was established in January 1998 by the industry to take over control and management of mines rescue services for Queensland's coal mining industry. All owners (as defined in the Coal Mining Act 1925) of coalmines in Queensland would become members of QMRS and contribute by way of a levy to fund its operations. A board of four directors would be responsible for the overall direction and management of the company.
In January 1999 new legislation was introduced which enabled QMRS, as an "accredited corporation", to provide mines rescue services.
In broad terms the intent of the new legislation is to provide for the following:

- Ensuring each underground mine owner provides a mines rescue capability for the mine.
- Accreditation of corporations to help underground owners provide a mines rescue capability.
- Allowing the Minister to fix performance criteria for accredited corporations.
- Have sufficient funding to meet the performance criteria.
- An inertisation capability

ISSUES INVOLVED

The Consol emergency management team (EMT) had been seeking support from QMRS and had subsequently asked for the GAG co-ordinator to assist the management team in identifying the technical aspects of the GAG and its operation. This would assist the EMT in their deliberations and subsequent decision regarding the use of inertisation with the GAG jet engine at the Loveridge mine.
The QMRS agreed to give as much technical support as possible, including sending the GAG co-ordinator to assist the Consol Energy EMT.
However, regarding the potential possibility of sending the GAG to the USA several important questions needed to be answered.

- Does it compromise the inertisation capability in line with the performance criteria?
- What are the ramifications in terms of equipment and personnel if we were to send one GAG unit and two teams to operate the inertisation system?
- What are the insurance issues with such a proposal?
- What are the risks to QMRS?

At this time the GAG had never operated outside Queensland, let alone in USA.
In fact the GAG had only ever been used once in a live fire situation, and that was at the Blair Athol Coal Project in September 1999.
Discussions were held with departmental officers of Natural Resources and Mines regarding the practical and political aspects of sending the GAG to assist Consol Energy.
In order to progress the issue it was decided to conduct a risk assessment by a team comprised of personnel from QMRS, mine operators and union check inspectors.
The risk assessment was to determine if the QMRS would compromise its ability to provide an "inertisation capability" if one of its two GAG units and two teams of operators were to travel to the US.
The unanimous conclusion of the risk assessment team, which comprised 12 people, was in favour provided a number of action points of issues such as availability of equipment and people could be addressed.
The 13 action points were completed by Monday 24th March; however, due to the outbreak of war in Iraq, a travel embargo had been declared by the mining companies. Most mining companies had lifted the travel embargo to the USA by 25th March, paving the way for the team to travel to the US on Thursday 27th March.
The GAG and its associated equipment were air freighted to the US on Saturday 29th March.
The logistics of preparing and organising the 7 tonnes of equipment under priority conditions was significant, and both Australian and American authorities co-operated with QMRS and Consol to achieve a remarkable outcome.

RESULTS

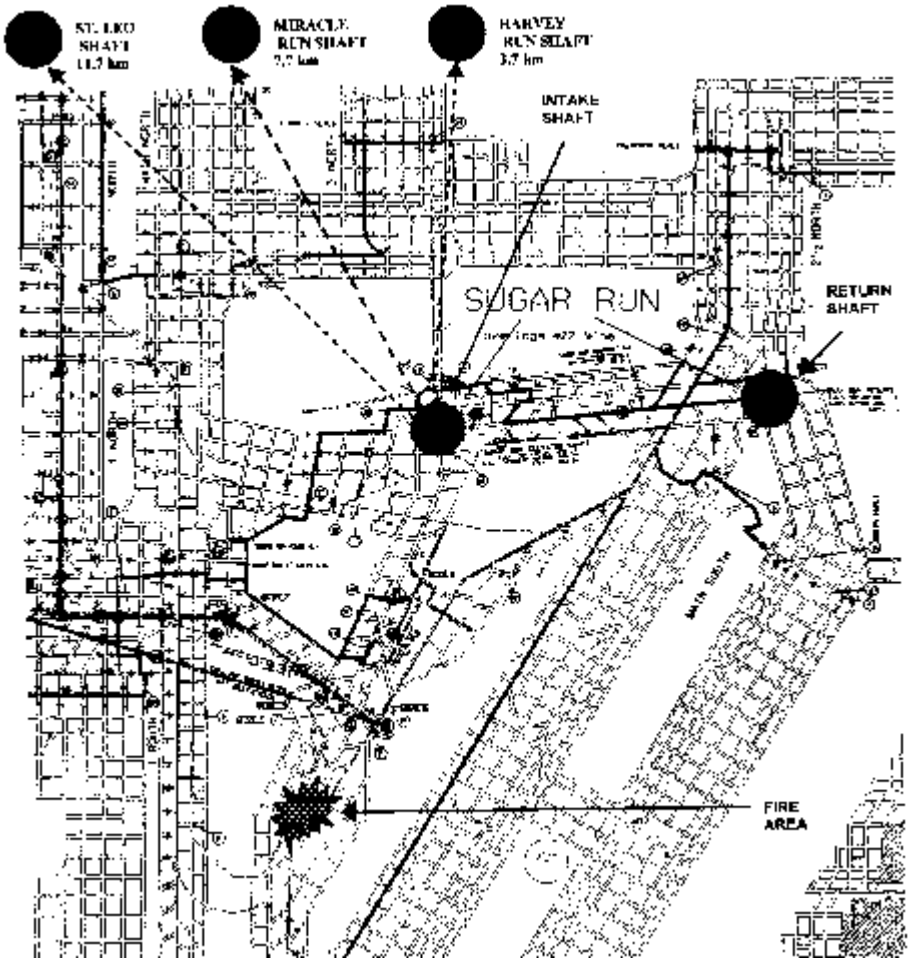
The inertisation of Loveridge Mine West Virginia, USA from the 27/03/03 to the 20/04/03.
A team from the Queensland Mines Rescue Service travelled to the USA on the 27th March 2003 to inertise the Loveridge Mine, which had been on fire since early February 2003. The team arrived from tropical, sunny Queensland to snow-covered Loveridge mine and needed acclimatisation to the cold weather.

A sequence of operational events follows

On Friday 28th March the team attended a meeting with senior Consol staff regarding the mine plan and application of the GAG at Loveridge mine. The following few days where spent acclimatising to the cold weather conditions

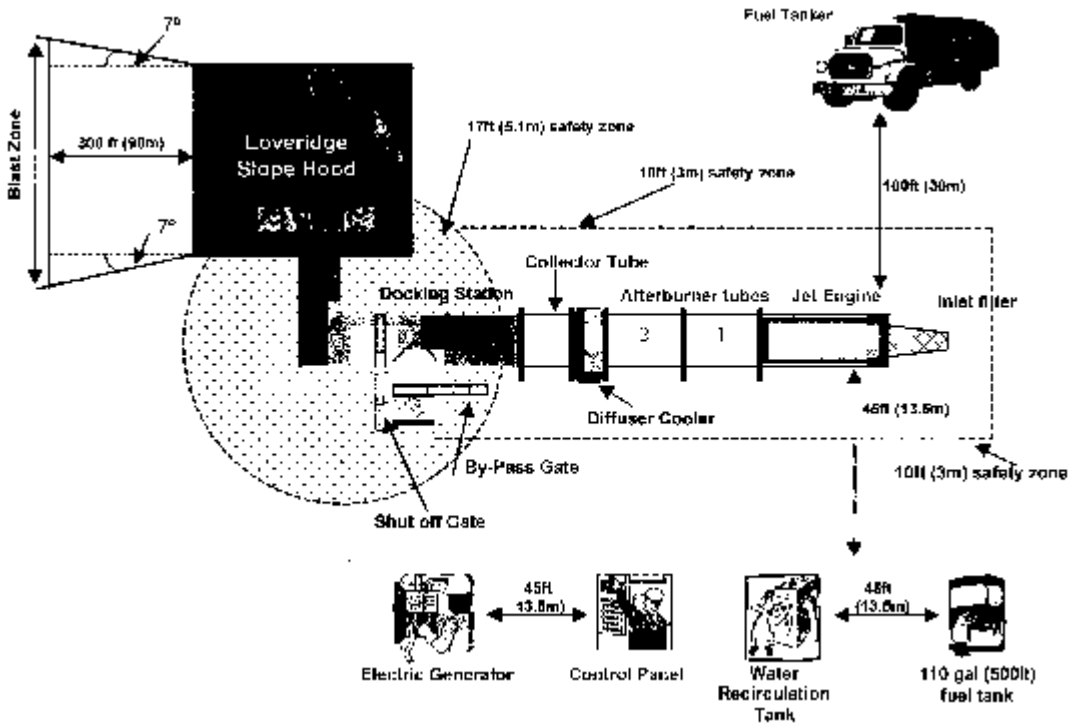
Loveridge Mine details
The mine is 335 to 366 metres (1100 to 1200 feet) above sea level and produces coal from the Pittsburgh No 8 seam using four continuous miners for the development of a longwall panel. The seam thickness is between 1.82 to 2.13 metres (6 to 7 feet) and the bottom of coal elevation range of slope bottom is 94 to 120 metres (380 to 395 feet) above sea level. The slope length is 902 meters (2959 feet). The coal is washed in a coal preparation plant at 1400 tonnes of raw coal per hour.
Figure 2 shows a mine plan of Loveridge Mine.

FIGURE 2: Loveridge Mine Plan



On Monday 31st March the team travelled to Loveridge Mine to undergo the mine induction programme and to overview the preparations which had been made to connect the GAG to the mine portal (see Figure 3).

FIGURE 3: GAG Jet Engine Installation and Blast Zone



On Tuesday 1st April a risk assessment was conducted between the QMRS team and Consol management to identify the main operational issues for use of the GAG system at Loveridge.

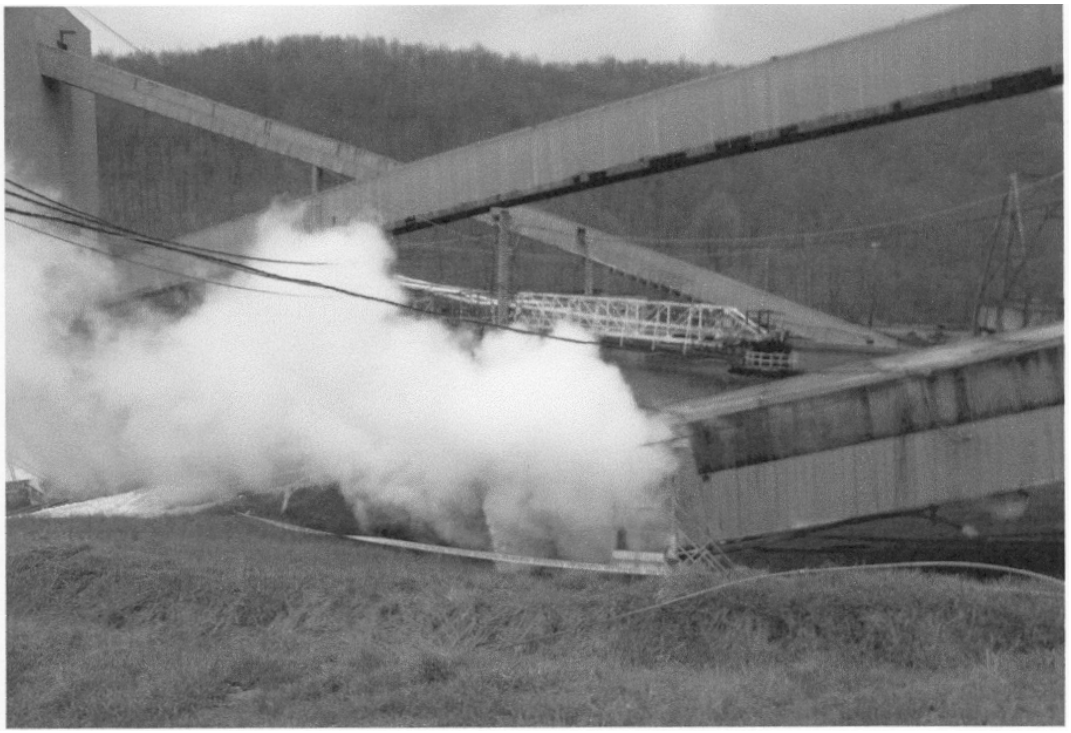
On Wednesday 2nd April the team visited underground operations at Blacksville No.2 Mine in Kuhntown, Pa with the aim of gaining familiarisation of US operations.

On Thursday 3rd April QMRS team members attended a meeting with Consol Management, United Mineworkers of America (UMWA), Mines Safety and Health Administration (MSHA) and the State of West Virginia Department of Mines Health and Safety at Consol's Administration office at Osage. At this meeting the GAG installation was discussed in some detail, including all the safety protocols. At this stage assembly of the GAG would commence on Friday morning 4th April with the expectation that it would be running late Friday afternoon. Discussions were held regarding the re-entry programme once the mine has been completely inertised. It had been previously estimated by the QMRS that the GAG would take approximately three days to completely inertise the mine.

Friday 4th April was the first day of GAG operations; two 5-man teams would operate the GAG on two 12-hour shifts. Assembly of the GAG was started with the day shift team and was completed by late afternoon. The GAG was assembled with very few problems, considering the distance it had travelled. All the appropriate protocols were checked and after all safety checks had been completed the jet was started up not being connected to the afterburner at 5.40pm The jet was exhausting to atmosphere via the exhaust door at 7.45pm The challenge was keeping the tubes cool, necessitating the deployment of additional water sprays to solve this problem.

The GAG started pumping down the mine at approximately 3.30am on Saturday 5th April. The GAG was now working very well; however, leakage of about 20 per cent to 30 per cent was escaping through the belt seal on the surface. This seal was built in order to seal the mine quickly, not for the pressures that would be generated by the GAG.
At 2.30pm the GAG exhaust was bypassed because of the risk of blowing the belt seal on the surface; the backpressure at the time was between 175 to 200mm (7 to 8 inches) of WG.
The GAG was stopped at 3.15pm after approximately 12 hrs of running time for repairs on the seal; the WG had reached 225mm (9 inches) (see Figure 4).

FIGURE 4: Seal after blow out

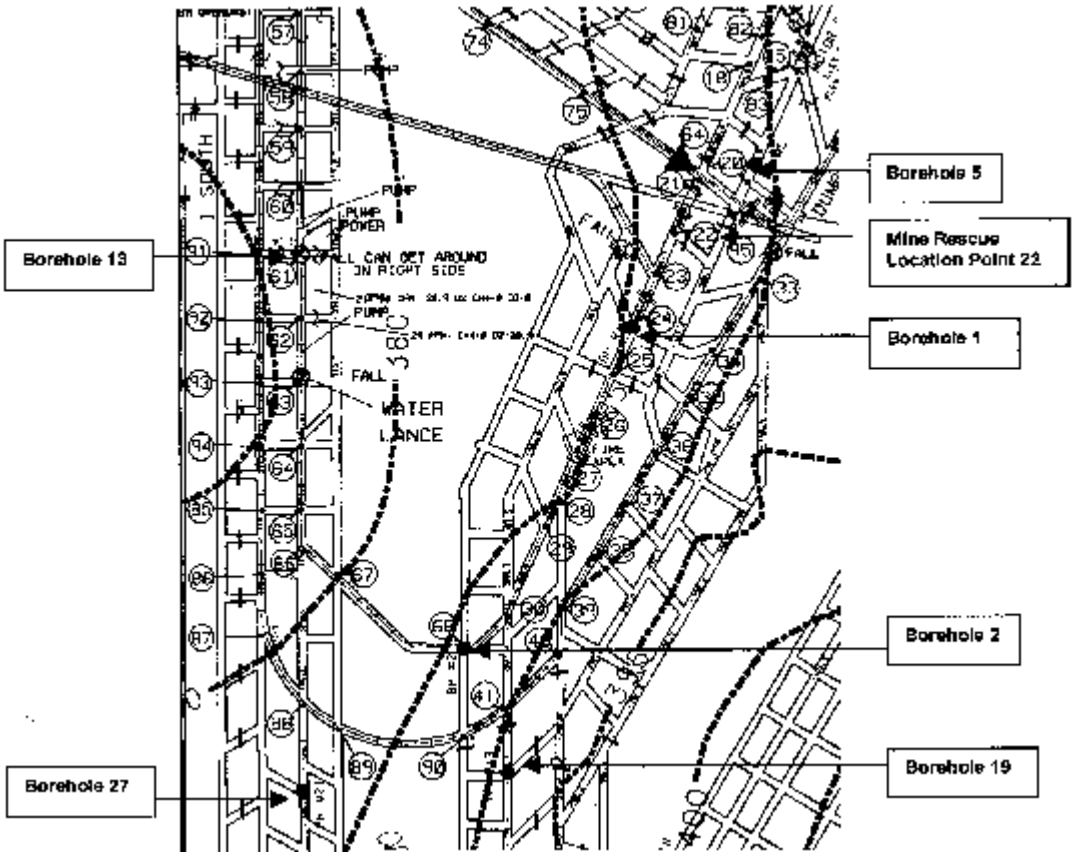


MSHA and Consol personnel were having some difficulty understanding the early gas readings in terms of the inertisation process. It took some time for them to appreciate that the most important reading was the oxygen content of the mine atmosphere, and that the basis of the inertisation process is to reduce the mine oxygen content such that it will not support combustion.
A meeting was held with MSHA and unions regarding the repairs to the seal on the surface. When a mine is sealed due to a fire underground MSHA immediately places a "K" order on the mine. This means that the parties concerned must agree on every single operation, then a plan has to be drawn up and approved by MSHA before any work can be carried out. Compared to the Australian risk assessment philosophy, it can be a very challenging process.
The repairs to the seal had to be completed without anyone working in the "Blast Zone" (see Figure 3).
A permit is issued for each step of the recovery operations from the "MSHA Command Centre", which was located at the entrance to the mine.

On Sunday 6th April the repairs to the seal on the surface were completed and the GAG commenced at 4.00am; WG was between 163 and 175mm (6.5 and 7 inches)
Discussions between MSHA and Consol were held in regard to relieving the pressure on the ventilation shaft at Harvey Run in order to reduce the backpressure on the jet engine. This was agreed to by the Command Centre.

On Monday 7th April, the fourth day of operations, the GAG stopped after approximately 43 hours of operation due to a problem with the fuel pump. The fuel pump was found to be defective; it was decided to connect the fuel line from the fuel tank, which was situated on a hill overlooking the GAG, directly to the jet engine under gravity. The GAG was fed fuel at pressure of 250Pa (10 psi). This was possible because the GAG engine pressurises its own fuel to the afterburner jets. A pressure relief valve was connected for the protection of the system. At the same time GAG maintenance was carried out, which included minor cleaning of carbon at the bottom of the afterburner rings. It was decided that whilst this work was being undertaken on the GAG, the seal on the surface would undergo further major repairs at the same time. The seal was injected with Rocklock.
In order to further relieve the GAG, suction was applied to borehole No.27 at 5.00pm, exhausting 26 cubic metres per minute (see Figure 5).

FIGURE 5: Sugar Run Slope and Fire Area



GAG pumping operations started at 4.00pm.
The shift sequence started at 9.00am with seven team members on the day shift and then 9.00pm with six team members on night shift. All team members on both shifts were given the option of one person taking a rest day on each shift on rotation.

On Tuesday 8th April the GAG was stopped at 2.00pm due to a hot spot on the afterburner. On investigation it was found that a build-up of carbon had occurred, which caused the afterburner rings to be distorted. New afterburner rings were required. The GAG was restarted at 4.00pm.
Hot gases were reported at St Leo shaft, which is the most westerly shaft at the mine and is approximately 14km from the GAG site, which means that we had established a circuit approximately 14km long. This was achieved after approximately 65 hours of GAG operations.

On Wednesday 9th April, the sixth day of operations, the GAG readings were as follows:
WG 87.5mm (3.5 inches), revs 8000, oxygen 4.8 per cent. The hot spot on the afterburner was moving around due to the build-up of carbon and distortion of the afterburner ring.
The GAG was stopped for maintenance after approximately 84 hours of running time.
The afterburner ring was found to be broken and the bottom area of the rings was solid with carbon (see Figure 6). New afterburner rings were fitted. Contractors using 309 stainless steel from plans produced by Consol engineers manufactured the afterburner rings. The GAG was restarted at 6.00pm. It was estimated that the fuel consumption of the GAG was 1827 litres/hour.

FIGURE 6

On Thursday 10th April, the seventh day of operations, the GAG was stopped for further maintenance. Engine carbon deposits still persisted. The inner afterburner ring was replaced and the GAG was started up again at 3.30am.

During the next maintenance it was necessary to change the engine oil from Shell to BP because we had exhausted the supply of the appropriate Shell turbine oil.

It was decided to stay with with the BP product and flush the whole system out in order to ensure that the best possible result for the running of the jet engine could be achieved.

MSHA produced Cowards Triangle graphs showing that at 11.00am, after approximately 102 hours of GAG pumping time, the St Leo intake and return shaft contained non explosive mixtures, which demonstrated that the whole mine was completely inertised. This was an historic moment for the GAG operations. A mine the size of Loveridge had been completely inertised and now recovery operations could commence (see Figures 7 and 8).

FIGURE 7: Loveridge Mine – St Leo Return

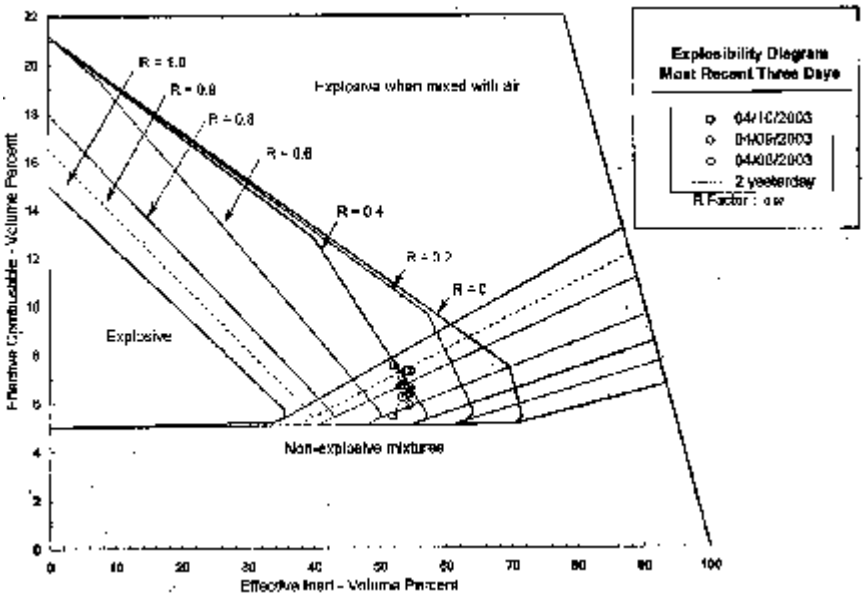
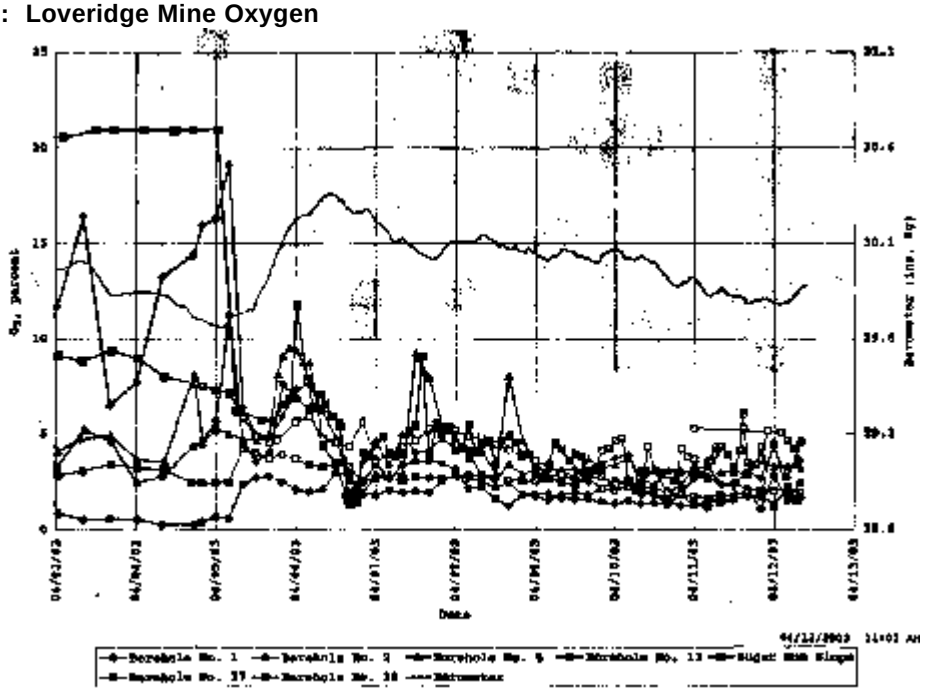


FIGURE 8: Loveridge Mine Oxygen



The borehole readings at 11.00am on 10th April for methane, carbon dioxide and carbon monoxide were as follows:

	CH_4 %	CO_2 %	CO ppm
Borehole 1	0.1	12.1	4200
Borehole 2	0.6	14.4	5300
Borehole 5	0.2	14.0	4100
Borehole 13	0.9	13.7	1500
Borehole 19	0.7	14.1	2400
Borehole 27	0.8	13.3	1700

Following discussions with MSHA it was agreed that the natural ventilating pressure and the barometer played a huge part in the problems associated with the high backpressure during the early part of the inertisation process. It was also agreed that roof falls underground may be a part of the backpressure problem.
Consol could now begin recovery operations, and in this regard they started to install a submersible pump in Sugar Run Intake shaft to pump water from the bottom of the shaft so as to get it operable again and allow rescue teams access to the mine. The GAG was stopped at 3.10pm for further maintenance and restarted at 6.40pm.

On Friday 11th April, the eighth day of operations, the GAG was stopped for maintenance. A cracked afterburner ring was replaced and carbon deposits removed. It was planned to flush the engine oil when the jet was restarted at the next service. The GAG was running at 8000 revs at 150mm WG. Consol's people were having great difficulty getting the submersible pump down the shaft. The video camera found that the pump was lodged at right angles in the shaft just above the water line. It was further established that all borehole samples were being taken at the bottom of the coal seam.

On Saturday 12th April it was observed that when the GAG was stopped, Sugar Run Intake out-gassed; and when the GAG started, the Intake in-gassed again. So when rescue people were working on the shaft it was important that the GAG was kept running.
GAG readings were 8000 revs, 150mm WG and oxygen 6.1 per cent. Consol was still having problems with the submersible pump. St Leo shaft was open and out-gassing at 11.15am.
Harvey shaft was also open.

The GAG by-passing gate was opened slightly in order to reduce the backpressure; WG dropped 50mm to 125mm WG. GAG stopped for maintenance at 3.30pm.
At this stage the afterburner had some slight distortion. It was important to maximise the continuous running time to complete the inertisation process.
The plan of the next stage of the programme was as follows:

1 Pump water out of Sugar Run (SR) elevator shaft.
2 Complete repair work in order to operate the SR elevator shaft.
3 Final service on the GAG.
4 Start St Leo fan.
5 Start Miracle Run fan.
6 Re-enter the mine via SR elevator shaft with rescue personnel.

On Sunday 13th April, the tenth day of operations, the GAG was started with the door cracked, backpressure 100mm WG. The backpressure had dropped to 50mm; the door was tightened to achieve 125mm WG. We had to ensure that the backpressure was kept at 125mm WG so that when starting the fans we had an appropriate safety factor to guard against any negative pressure on the jet engine. The St Leo fan started at 4.05pm and the Miracle fan started at 4.08pm, with no effect on the GAG backpressure.
The Harvey Run fan was started at 10.45pm and was stopped at 1.00am due to increased backpressure on the GAG. It should have had the opposite effect.

On Monday 14th April, the eleventh day of operations, the GAG was stopped for maintenance and re-started at 8.20am. Pumping water out of the elevator shaft was completed and an examination of the elevator shaft commenced. Rescue teams enter the SR elevator shaft to start the re-entry programme. Two rescue teams enter the mine at 10.30pm; they found good visibility with a temperature of 90ºF.

On Tuesday 15th April, the twelfth day of operations, the GAG was stopped for maintenance; one afterburner ring was changed and the engine ran much better. Rescue teams were establishing a new fresh air base and they were also finding quite a few falls of ground, which was causing them to make detours to get to the fire area. The GAG readings were 9300 revs, 62mm of WG, 5.5 per cent oxygen.

On Wednesday 16th April rescue teams found a fall inbye the dump station at the bottom of the slope, which limited their options regarding access to the fire area.

On Thursday 17th April, the fourteenth day of operations, water was being pumped from borehole 13 in order to gain access to the fire area (see Figure 5). Water was now being pumped from the second and third pumps. The mine had been inertised for some days now and the plan was to shut down the GAG permanently at midday on Friday 18th April. This date had been extended from Wednesday 16th. Consol's Chief Operating Officer – Coal asked if the GAG could stay for a further two days. This was agreed to, resulting in the GAG being dismantled at midday on Sunday 20th April.

On Friday 18th April, the fifteenth day of operations, the GAG was stopped at 2.30pm and put on standby after approximately 240 hours running time (time pumping into the mine).
Consol personnel continued to pump water from the fire area so that it could be sealed off. The rescue teams had found evidence of a fire in the roadways south of the coal and materials slope, which were full of water approximately one metre deep. The fire was active in the roof of the coal seam.
Consol personnel started to pump nitrogen down No.1 and No.2 boreholes (see Figure 5) in order to cool the area down. When the water had been pumped out they were in a position to seal the roads south of the coal and materials slope, and still allow access for coal and materials transport via the slope without having to drive an additional roadway for access.

On Saturday 19th April, the sixteenth day of operations, the GAG was on standby until noon on Sunday 20th April. Consol personnel continued to pump nitrogen down boreholes No.1 and No.2 at 34 cubic meters per min; the fire area was cooling down. Mine rescue teams were working on a fall at location 22 (see Figure 5). The temperature had reduced to 120ºF.
Eleven rescue teams were working on the recovery operations at Loveridge Mine. They were working on a 2 hour change-over. The rescue teams were waiting for the fire area to cool down before they could advance towards the fire area.

The gate door inbye of the jet engine was opened for the slope to exhaust (outgas) to atmosphere. An auxiliary fan was hooked up to the door ready to exhaust in the event of the slope starting to ingas. The rescue teams were in the process of establishing a route underground in order to get materials to the sealing sites.

On Sunday 20th April, the seventeenth and last day of operations, nitrogen continued to be pumped down boreholes No.1 and No.2. Borehole readings were being maintained at low oxygen and CH_4.The rescue teams now had control of the fire area.
It was suggested by QMRS and some Consol personnel that preparations should be made to seal the area so that the fire area could be flooded. The contours favoured this approach, and there would still be access to the coal transport and supply slope. This option was being discussed when we left the mine at midday. The temperature in the rescue working areas was down to 90ºF.
At 10.00am QMRS started to dismantle the GAG, and this was completed by 1.00pm.

Fact Sheet on the GAG-3A Jet Engine

- The jet engine weighs about 700kg and fully assembled it is about 12 metres long, weighing a total of 2.5 tonnes. The total weight including support equipment is 6.8 tonnes. It is carried by truck and takes about three hours to assemble.
- A generator is used for all auxiliary electrical power such as water pumping requirements, electrical gas monitoring and area lighting.
- In use the de-thrusted jet engine draws in and compresses air in which fuel is burned in its turbine chamber to power the unit. The air then passes to the afterburner where additional fuel is burned to reduce the oxygen content to less than 1 per cent. Hot gases then pass into water-cooled delivery tubes and finally water is injected into the gas stream, which vaporises.
- The unit produces between 25 and 30 cubic metres/second of water-saturated misted gases at a temperature of 81 to 85ºC, which equates to about 10 cubic metres/second of dry gas after condensation of water content.
- The unit requires six people for the start up and shut down sequence and three people to maintain operations.
- Fuel burn is about 1600 litres/hour – Jet A1 fuel.
- Engine revolutions running idle are 7500 to about 10000 revolutions/minute
- For cooling and water injection a minimum water supply is about 11 litres/second for closed cycle operations.
- The GAG was developed in Poland and has been used in Polish and Czech mines to good effect. It has also been used in South African gold mines for the last six to seven years to control fires in timbered stopes.
- GAG was first used at Blair Athol mine in central Queensland in September 1999 when it successfully extinguished a large fire.
- Products of combustion are nitrogen, carbon dioxide, water vapour and trace elements. A typical gas analysis is as follows:
  - 85 per cent nitrogen
  - 13 per cent carbon dioxide
  - 1.6 per cent oxygen
  - 0.4 per cent carbon monoxide

CONCLUSIONS

- The inertisation of Loveridge Mine was a successful venture in which two countries co-operated to further the advancement of mining technology.
- It was a collaborative effort of Consol Energy, the Queensland Mines Rescue Service, the National Institute for Occupational Safety and Health, the US Department of Energy, the United Mine Workers of America and the Mines Safety and Health Administration.
- On 10th April 2003, after approximately six days and 102 hours of GAG pumping time, graphs produced by MSHA of the Cowards Triangle showed that from the slope entrance to the most westerly shaft at St Leo, a distance of approximately 14km, the mine was completely inertised. In other words, no explosive mixtures existed at any of the monitoring points in the mine.

- To our knowledge this is the first time that one GAG jet engine has operated for some 240 hours over a period of 13 days.
- When the GAG first started operations the MSHA and Consol personnel were having some difficulty understanding the gas readings from the monitoring points (boreholes) due to the complexities of the inertisation system. It took some time for them to understand that the main purpose of the inertisation process was to reduce the mine oxygen content such that it would not support combustion.
- The effects of the barometer, the mine natural ventilating pressure and roof falls underground had considerable influence on the backpressure that the GAG had to overcome in order to operate effectively.
- During the period of operation the backpressure on the GAG was such that it created major issues of maintenance of the afterburner rings. Towards the conclusion of the exercise the afterburner was somewhat distorted due to the build-up of carbon deposits. We did not have a spare afterburner and for the safety of the initial recovery operations we just had to keep the unit operable.
- Compared to the Queensland coal mining industry's risk assessment philosophy it may be considered that the way that MSHA controls every operation can be a very time-consuming and challenging process.
- The Australian team members carried out their duties in a very professional manner; they were good ambassadors for both their country and indeed the Queensland Mines Rescue Service during the GAG operations at Loveridge.
- Finally, it would be remiss of me not to mention the wonderful hospitality and comradeship afforded to the Australian team by Consol Energy personnel during the inertisation process.

RECOMMENDATIONS

- That hydraulic doors be fitted to the sliding gates, which control the airflow on the GAG exhaust.
- During similar operations it would be advantageous to have an additional afterburner and afterburner rings.

ACNOWLEDGEMENTS

- I would like to thank Mr John Urosek from MSHA for his help during the exercise and the graphs he produced during the inertisation of Loveridge Mine.
- I would like to thank Mr Brett Harvey, the CEO of Consol Energy, for the opportunity for QMRS to be involved in this successful inertisation of the Loveridge Mine.
- Thanks to Mr Wayne Hartley and Mrs Sue Williams from QMRS for their assistance in producing this paper.