

A breath of fresh air

Carly Lovejoy looks at mine ventilation systems and their utilisation

The main function of an underground ventilation system is to provide a safe, comfortable working environment in all accessible areas of a mine.

This means that:

- Contaminants including explosive fumes (containing nitrous oxide and carbon monoxide), airborne dust, and naturally occurring gases such as methane, carbon dioxide, hydrogen sulphide and radon are diluted to safe levels by airflows of sufficient quantity and quality;
- Sufficient oxygen is supplied to workers underground;
- Air temperature, speed of movement and humidity remain between the legal maximum and minimum levels, and at a comfortable level as far as is practicable.

Ventilation regulations and associated legal levels for contaminants, temperature, air speed and oxygen vary from country to country. These are mainly dependent on: which commodities have historically been mined; the general labour legislation; past accidents; the level of scientific knowledge regarding pollutants and to what degree this knowledge has been translated into legislation; and the legislative, political and social environment of the country.

The circumstances in which it is comfortable for personnel to work are subjective, and vary strongly between region and country. The main aims should be the prevention of fatigue, overheating, and under-cooling, which could negatively affect health and safety. Conditions should be reasonably comfortable as far as can practicably be arranged. As the layout of a mine is constantly changing, the effectiveness of the ventilation system will vary over time.

Jurgen Fuykschot, senior mining engineer at SRK Consulting (UK), explains: "Engineers designing a mine should always be aware of the local mining legislation and regulations with regard to ventilation. Awareness of international best practice standards and available equipment may lead to better or more efficient mine designs, especially when specific mining regulations are non-existing or outdated and can possibly be changed.

"Mines producing the same commodity

located in similar climatic regions can be used as examples and benchmarks, such as uranium mines located in the Russian and Canadian Arctic, although each operation should be treated on an individual basis."

KEY COMPONENTS

Primary ventilation systems have three key components: all underground workings, including the main adit or decline, capital development, main shaft, stopes and production areas; specific ventilation workings such as ventilation shafts, raises and drives; and the ventilation equipment, including the main fan required to circulate air through the primary circuit. In addition, ventilation controls such as walls, airlocks, stoppings, air crossings and regulators can be added to improve the function and control of the primary ventilation system.

Primary ventilation fans are generally in continuous operation to keep a constant flow of air moving underground. Coal mines are always ventilated by parallel primary vent circuits as methane can build up in the air if too many workplaces are ventilated by the same flow. Uranium mines need to have single-pass flow through ventilation systems to remove radon gas as quickly as possible as the daughter products of radon, which are formed within a short time, are more dangerous than radon itself.

Daniel Stinette, senior ventilation engineer at Mine Ventilation Services, says: "The type of fans used varies, depending on the system parameters, and can include combinations of vane-axial, centrifugal and mixed-flow fans from 5-3,000kW, arranged in parallel or series on the surface or underground. Primary and booster fan arrangement varies, according to a variety of system parameters, and should be optimised through the use of modelling software."

Rob Pope, vice-president of Jet Air, explains: "Generally, if one larger fan can meet the performance level required, two smaller fans will be chosen instead. If one fan experiences a failure, at least 50% of the ventilation is operable until repairs are made. If a fan is a critical part of the operation, a spare fan or parts are



important to have in the warehouse. In a metals mine this may mean continuing operations; however, in a gassy situation such as a coal mine it may mean keeping explosive gases from building to dangerous levels."

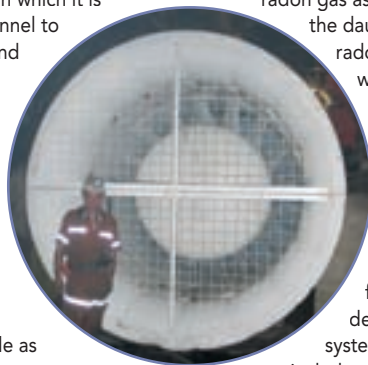
Secondary ventilation is used in development headings and production areas at the end of drives. Fresh air is brought to the working area from the primary ventilation system by an auxiliary fan, via vent ducting, and flows back in the drive. Secondary ventilation fans are turned off during blasting in each heading to prevent damage to the vent bag, and therefore need to be located in a safe location, which is ventilated by the primary system. Extra components such as ancillary control systems for dust suppression, gas drainage, refrigeration and heating systems can be added to ventilation systems with specific requirements.

Mr Fuykschot comments: "Primary surface fans range from 200kW to 1MW, while auxiliary fans range from around 25-200kW. Each fan type has a specific fan curve, which describes the relationship between pressure rise and volume flow rate for a constant impeller speed (rpm). Similarly, the relationship between pressure loss and volume flow rate is the most commonly used system characteristic. Ideally, the duty point is close to the peak efficiency of the fan."

To determine the size of key ventilation system components, SRK recommends modelling the system using specific programs such as Ventsim, VnetPC and VUMA to simulate the ventilation network and optimise the design. By combining the mining schedule with the ventilation design, capital expenditure can be planned. Programs such as Ventsim and ClimSIM can also run thermodynamic modelling to determine the size of heating or cooling installations, where required.

To ensure all these components are in

"Ventilation regulations and associated legal levels for contaminants, temperature, air speed and oxygen vary from country to country"



At Sao Bento mine in Brazil, Cogmacoustic installed a single stage fan with 16 blades



place, have the correct capacity, run properly and are adequately maintained, continuous monitoring systems can check that fan operation, gas content, air speed and temperature are at the correct levels. Dedicated ventilation personnel are a legal requirement in most countries when designing and maintaining ventilation systems for mines, and it is important that management adopts a good ethos towards staff safety.

SYSTEM DESIGN

Ideally, ventilation engineers would be involved from the early mine-design stage to prevent the need for costly correction later on, which could affect production if the capacity of the ventilation system is under-designed.

When designing mines and suitable ventilation systems it is important to take into account the commodity or product being mined. Requirements will vary widely as some mines will experience higher levels of potentially toxic or explosive gases released during the mining process or generate more dust than others.

Coal mining releases methane, which can build up to potentially explosive levels if it is not properly regulated. Coal mines are often extremely dusty due to the nature of extraction. This dust is susceptible to spontaneous combustion and can cause numerous respiratory conditions such as black lung during prolonged exposure. Uranium mines produce high levels of radon, which builds up in confined spaces, exposing workers to background radiation and it can cause diseases such as radon poisoning or lung cancer.

Operations that extract sulphide-type ores often produce hydrogen sulphide in large quantities, which can cause oxygen deprivation and sulphide dust explosions. Fibrous materials such as asbestos, the particles of which are released into the air during mining, can cause fibrosis over

time if their inhalation is not prevented.

Mr Stinette explains: "Varying ore types and mining methods dictate the type of ventilation system required. For example, gassy coal mines would require significant attention to the dilution and removal of methane. Equally, coal mines, which are susceptible to spontaneous combustion, would require a different approach. In metal mines, the difference in ventilation systems for a small, narrow-vein and high-grade deposit and a large-scale and highly mechanised operation can differ in both scope and size."

Mr Fuykschot says: "The final ventilation system should be designed to operate at the maximum expected capacity of the mine, with enough spare capacity to account for factors such as leakage, blockage by machinery and expected gas inflows. The ventilation system capacity is ideally linked to the life-of-mine plan to prevent under and excess design capacity. Under-capacity can lead to unhealthy and unsafe situations, and may cut or limit production levels. Excess design capacity after the maximum production capacity is reached leads to unnecessary operational costs such as power and maintenance."

The type, size, work location and mobility of mining machinery must also be considered during the design phase. This is directly related to production levels, and all machinery, particularly diesel-driven equipment, requires sufficient ventilation to work at optimum levels. If insufficient ventilation is provided, areas of the mine could potentially be shut down.

The mining method itself – whether it is mechanised or uses blasting – the amount of explosive used per tonne, and the amount of broken material and dust generated also need to be considered. With regard to mine layout, the capital access method – ie decline, adits or shaft – need to be designed with production and ventilation requirements in mind as changing the size of a shaft after development is very costly and will halt production. Vertical and lateral expansion will also influence the number and size of extra ventilation openings, such as raises and drives, required.

Mines with decline access are generally located closer to the surface than those accessible via shafts. Increased (relatively cheaper) access to the surface environment will have a big impact on ventilation system design and infrastructure requirements. Near-surface mines typically require less (or zero) cooling than deeper ones.

Various emergency scenarios will need to be factored into the ventilation design,

the most common being the planning of egress routes and/or refuge locations in the event of an underground fire.

Dariusz Holod, ventilation expert at Stantec Mining, says: "The most common emergency factored into mine design is underground fire. Ventilation system designs will include escape-ways, fire doors or even the reversal of ventilation fans. There is mine fire-evaluation software that can be used specifically for ventilation design at coal mines."

Geographical location, surface climate, virgin rock temperature, thermal gradient and depth of mine will determine the need for additional heating or cooling. Heating is generally undertaken on the intake air to prevent ice forming in shafts and ensure comfortable working conditions. However, heating may lead to lower geotechnical stability of the surrounding rock at operations located in permafrost. ►

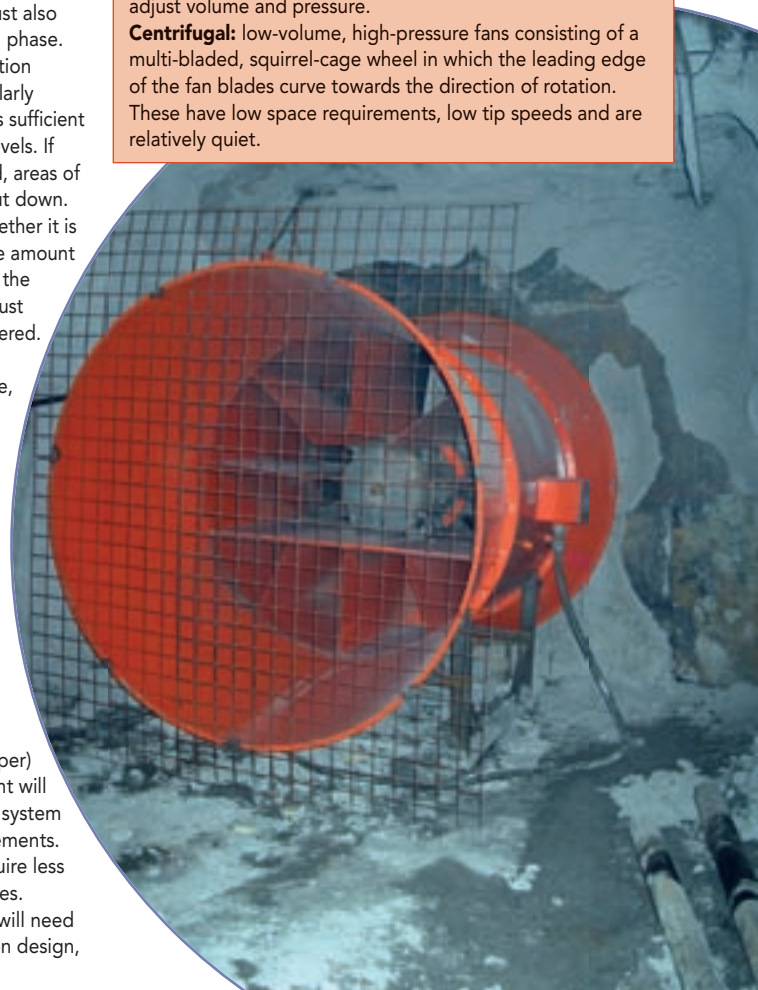
Two-fan mine ventilation system, exhausting out of a vent raise

Jet Air fan mounted in a bulk head

Fan types

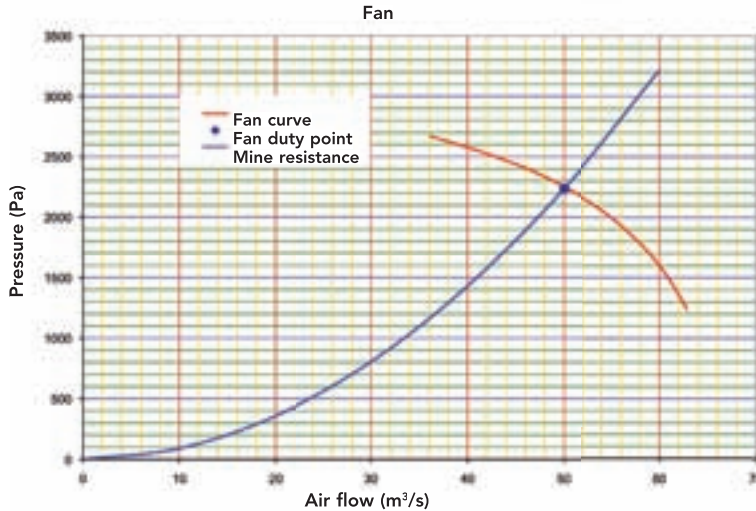
Axial: high-volume, low-pressure fans either directly driven by the motor shaft (motor inside the tube body) or remotely driven using belts (motor outside the tube body). Volume is adjusted by setting the pitch of the adjustable blades on the rotor and, in some cases, motor speed can be tailored to adjust volume and pressure.

Centrifugal: low-volume, high-pressure fans consisting of a multi-bladed, squirrel-cage wheel in which the leading edge of the fan blades curve towards the direction of rotation. These have low space requirements, low tip speeds and are relatively quiet.



The fan duty point and its curve illustrate fan performance when confronted with the total mine resistance

“Ventilation system capacity is ideally linked to the life-of-mine plan”



► In deep mines, air heats up due to adiabatic compression in the downcast shafts, combined with the heat generated by machinery and the rock mass, so it can be difficult to cool the air sufficiently without a refrigeration plant. Although extra capital and operating costs are associated with refrigeration plants, and their application is limited to certain areas, operations are often made possible thanks to their use where, otherwise, legal limits would prevent staff from working.

Sufficient space must be designated in

advance to prevent downtime caused by the development and installation of refrigeration equipment in shafts or drives.

Nabil El Hajjam, ventilation sales engineer at ECE Cogmacoustic, says: “The cooling plant is always fitted to the inlet network. Because it is cumbersome and requires a lot of energy, it must be installed near the electrical network. It also generates a lot of heat, which is not desirable inside the mine. The cooling system produces head losses, which need to be taken into consideration

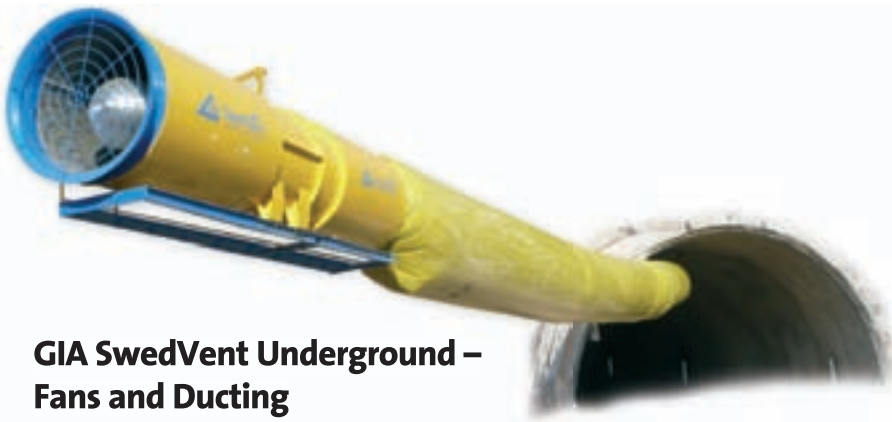
for fan power and size calculation.”

Mr Holod adds: “In most cases, newly designed cooling systems are located on the surface. It is also common to design ventilation and cooling systems as part of a mine expansion when new ventilation shafts or raises are added. Some existing mines use underground cooling systems because the surface infrastructure does not allow for the construction of big cooling plants.”

MANUFACTURERS & ENGINEERS

Suppliers of mine-ventilation system components include: ABB; ABC Industries; Accutron Instruments; Agapito; American Mine Door Co; AMCO Plastics; Austcold; Bluhm Burton Engineering; CIMCO; ECE Cogmacoustic; Continental Fan; Daltec Industries; EOL Vent System; FläktWoods; GIA Industri; Howden; Jet Air; JP Jensen; Korfmann Lufttechnik; Mine Ventilation Services; Mining Equipment; Minova; Mirarco; NRCan; Proton; Rocvent; Schauenburg; Stantec Mining, and Zitron.

A number of engineering and design consultancies, such as SRK Consulting, provide services for mine ventilation design, installation and operation. *Mining Magazine* spoke to a selection of suppliers and consultancies to find out the scope of services and products on offer.



GIA SwedVent Underground – Fans and Ducting

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- Precise hub-casing design (small gap between the casing and blade tip).
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- Heavy duty design for mining and tunneling.

Facts

Diameters: from 0.500 up to 2.240 mm
Motors: from 5 up to 500 kW per stage
Air flows: from 3,0 up to 175 m³/s per stage
Pressures: up to 6.000 Pa per stage
Stages: 1-5 stages per fan-station



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- Kiruna Electric Truck
- Diesel Locomotive
- Rescue Chamber





Two-stage fan at Sao Bento mine, installed by Cogmacoustic

ECE COGMACOUSTIC

Cogmacoustic designs and manufactures ventilation solutions tailored to each mining project. Its scope of supply includes: primary and secondary axial fans; wet and dry dust collectors, and electrical control systems. In addition, ventilation training, audits and air-quality measurements can be provided on request.

Mr El Hajjam says: "Our ventilation systems are used in mines in Europe and North Africa, particularly in Morocco, but we have also equipped gold mines in South Africa, Mali, Niger, Brazil, Indonesia and the Philippines. Some recent projects are located in Turkey, Canada and Zambia. Some of our largest customers include Managem, Ma'aden Gold, Randgold Resources, Areva, Arava Mines, Antam, Vale Inco and VKG."

In 2000, Cogmacoustic installed two new fans in parallel at a Compagnie Minière des Guemassa (CMG) base metals

Common ventilation controls

Stoppings: used to close off cross-cuts to prevent the air in one entry from moving into the return air of the adjacent entry. Permanent stoppings are made of concrete blocks or other non-combustible material. They are used in areas where ventilation is well established and are tightly sealed against the sides of the tunnel (but often include doors for miners). Temporary stoppings are used in working sections of the mine where ventilation is changed as needed and are usually made of canvas, brattice cloth or plastic.

Check curtain: made of brattice cloth, canvas or plastic, they are hung across a passageway, but are open to let miners or machinery pass. They fasten only at the top and deflect intake air into the working area.

Line brattice: used to course air from the last open cross-cut to the working face. It is extended as mining progresses to keep the air flowing to the face. Brattice extends from the end of the check curtain to within 3m of the working face.

Overcasts & undercasts: intake and return air paths often intersect. As a result, overcasts and undercasts are built to allow the two air currents to cross without causing a short circuit. Undercasts are seldom used unless the roof is unstable as they tend to fill with water or debris, which would slow down the air current.

Mine doors: used to control ventilation in areas of heavy traffic such as main haul roads. The doors are usually hung in pairs to form an airlock, which prevents a change in ventilation when one of the doors is opened. The doors can be manual or automatic. If manual, they are hung in such a way that the air pressure will close them if they are left open accidentally.

Regulators: used to ensure proper air distribution, regulators are designed to meet the needs of each air split. Located in return airways, they are often sliding doors/windows built into permanent stoppings.

Box checks: conveyor belts are usually in or near intake air passages and, to avoid pollution in the event of a fire, they need to be isolated from the main airways. Box checks are stoppings built at either end of the belt to limit the intake air flowing over it.

mine in Morocco. The exhausted air was very abrasive and the firm made fans with stainless steel impellers to improve their lifespan. Cogmacoustic also undertook two separate projects at Eldorado Gold

Corp's São Bento mine in Brazil from 2005-06, installing a single-stage and a two-stage fan, both with 16 blade impellers, to meet the extraction requirement of 95 m³/s at 5000Pa. ►

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AXIAL FANS FOR MINES

Cogmacoustic manufactures energy efficient fans for mining applications. As a result of innovative design, the company's fans are capable of supplying a higher airflow/absorbed power ratio than equivalent conventional axial fans.

Cogmacoustic's standard range of fans is capable of supplying airflow of 5m³/s to 230m³/s (11,000cfm - 500,000cfm) at a working pressure of 250Pa to 7,000Pa (1in - 28in w.g.) per stage. Comprised of one, two or three stage configurations, Cogmacoustic offers varying levels of sound insulation, enabling customers to find the just balance between budget and environmental requirements.

COGMACOUSTIC - FAN SYSTEMS AND DUST REMOVAL EQUIPMENT FOR MINES

With more than three decades of experience in the ventilation and air treatment of mines, tunnel excavation and other underground works, Cogmacoustic has become one of the most reputed suppliers of dedicated fan systems and dust-removal equipment in the world.

Cogmacoustic provides:

- Economic and silent installations - through the use of frequency inverter equipped electrical cabinets, significant power savings may be realised (25%). The modular construction of our fan/silencer units yields exceptional performances at low noise levels.

Zitron primary fans installed by SRK Consulting

► In 2009-10, the company installed a specially designed secondary ventilation fan at Loulo gold mine in Mali, called 'The Magic Fan', which is capable of supplying fresh air to the long galleries while maintaining an acceptable sound level.

MINE VENTILATION SERVICES

MVS offers a range of engineering services and products for underground mine ventilation, including: design and optimisation; future modelling; cost benefit system analysis; heating and cooling calculations; climatic simulations; diesel-particulate matter measurement and control; shaft sizing and optimisation; training; and software packages for ventilation modelling, fire simulation and climatic analysis.

MVS has worked on six continents and in most major mining regions. The majority of its clients are located in North and South America.

The company is currently involved in a number of projects, such as: the design of ventilation systems for new block-cave mines; fire-modelling for a large system of interconnected mines; and optimising the size, location and timing of new shaft constructions for a longwall coal-mining operation.

"The Magic Fan is capable of supplying fresh air to the long galleries"

STANTEC MINING

Stantec offers: mine ventilation modelling; ventilation infrastructure design (structural, electrical, automation and mechanical); and main fan selection and auxiliary ventilation system design, plus cooling and heating system design for underground mines.

Stantec regards firms such as Vale-Inco, BHP Billiton, Rio Tinto, Mosaic Mining and Carmen Copper as some of its main clients. Mr Holod says: "One of our most interesting and challenging projects was the design and installation of ventilation systems for the Panda mine at BHP's Ekati diamond operation in the Northwest Territories. Access to the Panda mine was via the same decline as the Koala North mine.

"Due to varying depths, Koala was located in permafrost, while Panda was below the permafrost. Koala had no heating system requirements, but the Panda mine encountered water below the permafrost line and needed an air-heating system. The design had to take into consideration extreme weather conditions such as temperatures as low as -45°C, high winds and drifting snow, and lack of natural gas or propane commonly used to power heating systems."

With only diesel fuel available, an indirect heating system had to be used. The design of the instrumentation and



automation was probably the most complicated aspect. These had to include: changes in air quantities (reduction in air flow during shift change = reduction in diesel fuel consumption); changes in outside air temperature; a 2-4° variation in underground air temperature, and remote operation of the system.

He adds: "The start-up and initial operation of the Panda #1 ventilation fan and heating system was successful, with few challenges. The most significant was the use of a 'waste engine oil' system instead of diesel fuel. Initially, the oil delivered to the system was dirty and caused plugging of the burner nozzles. This was solved by pre-cleaning the oil and mixing it with cleaner diesel fuel.

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ventilation systems for compliance with regulation, and help with ventilation surveys and updating emergency plans.

From 2003-07, SRK worked on the upgrade and expansion of ventilation facilities as part of the mine expansion at Consolidated Minerals' Beta Hunt nickel mine in Western Australia. The mine was restarted in 2003 after being mothballed. The Beta deposit was mined immediately after reopening and rehabilitation, but the Hunt deposit was abandoned. Instead, the focus was on developing the link between the Beta and East Alpha orebodies.

Geological information indicated a large resource in the East Alpha and Beta south extension, which required further exploration. Access to these areas is far from the surface and the ventilation system serving the mine was incapable of supplying the air quantity required for all of the new mining and exploration.

SRK created a two-stage strategy to deal with the immediate exploration requirements, and future development and production requirements of the mine. This included: a full evaluation of the current mine ventilation infrastructure; creation of a ventilation model for computer simulations; a ventilation upgrade study, based on a mining study; and a subsequent equipment and system design upgrade. ♥

Mine ventilation installation at Flying Fox mine, Forrestania, Australia

“Panda mine encountered water below the permafrost line and needed an air-heating system”

“Problems associated with air temperature measurement and control were resolved by the relocation of air temperature sensors from the fan elbow to the bottom of the ventilation raises. The subsequent design of the Panda #3, Koala #1, and #2 fan and heating systems included all the enhancements applied to the Panda #1 system.”

JET AIR

Jet Air makes a line of axial flow fans from 46-213cm in diameter, all supplied with aluminium hubs and adjustable, forged aluminium blades. Fans are available in standard and silenced configurations. “As well as fans, we offer all the hardware to complete the installation such as cones,

screens and mounting stands. Jet Air also supplies spiral, steel ventilation ducting, rolled on site,” adds Mr Pope. Jet Air fans are mainly sold to clients in North America.

SRK CONSULTING

Underground mining engineers at SRK have the capability to design a mine layout and the associated ventilation system for most scenarios. For specific requirements, such as the design of heating and refrigeration installations or uranium mining, associate specialists are available. For coal mining, expertise on ventilation and methane extraction is provided by SRK’s coal-mining division.

The firm offers a four-day, on-site mine ventilation training programme for engineers. The course demonstrates the sequence and work structure required to provide essential ventilation services, efficient operation of the system and compliance with mining and health regulations. In addition, SRK can undertake reviews and audits of



SUPERIOR

Fans with forged blades

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