Controlling the flow

Howden was previously awarded a contract for the installation of the main ventilation fans at Codelco's Chuquicamata underground project in Chile, one of the world's largest underground mines (Credit: Howden)

There is more to underground mine ventilation than volume, Dan Gleeson reveals

The topic of mine ventilation is set to become a lot more complex with the incorporation of new technology, equipment and regulations.

Operations will have mixed fleets of diesel and electric equipment alongside a blend of manual, teleremote, semi-autonomous and autonomous equipment.

These operations will be mining at different depths depending on the orebody in question and be governed by various regulations that dictate the amount of fresh air needed to be blown in.

This is before factoring in the different mining methods, sizes of operation, financial capabilities and average number of blasts per week.

Against this evolving backdrop, an optimal, efficient, and cost-effective ventilation system will have to be much more sophisticated than those that preceded them.

Take back control

"Shortly, I think mine ventilation control will be even more important," Jan Nyqvist, **ABB** Product Manager, Automation Underground Mining, told ***IM***. "If you look into ventilation systems of today, we are using them for several things."

Pushing air into working areas to improve the operating environment is the most important use, Nyqvist suggests. This includes ventilating for good air quality, the right working temperature, dust reduction, etc.

This application is closely followed by ventilating blasting gases, a process that allows workers to return to the face quickly and safely after a blast. Here, a combination of ventilation fans and environmental monitoring stations distribute air and analyse the environment to ensure workers come back to production areas only when it is safe to do so.

"Then, the third one is to ventilate the air from diesel particulate matter," Nyqvist said.

It is this latter application coming into focus today as miners plan for, trial or buy new battery-electric or tethered-electric equipment to reduce their emissions and, in many cases, cut ventilation costs at their operations.

"That ventilation demand from diesel particulates will be removed a little bit with the use of electric vehicles," Nyqvist explained.

In Canada, for example, operating companies have to ensure that for every one brake horsepower of diesel emitted, 100 cubic feet per minute of air (1 kw/0.06 m^3/s) is pushed into the operating area.

"From a battery-electric vehicle perspective, if the whole mine is electric, you are taking out the 100 cfm/bhp rule of thumb," Randy Ouimet, Sales Executive at **SHYFTinc**, part of the Inovinta Group, told ***IM***.

Without the need to ventilate diesel tail pipe emissions from mining equipment, the amount of air needed to be blown in at mine sites in Canada will fall, meaning the fans installed underground could get smaller in size.

Former Senior Project Engineer at Goldcorp (now Newmont), Maarten van Koppen, illustrated this in a 2018 blog post reviewing the construction and initial operation of the Ontario-based Borden mine – billed as the world's first all-electric mine.

He said the absence of diesel equipment at the mine had not only significantly reduced ventilation requirements and costs, it had also impacted the design of the mine itself.

"Drifts are now designed to be smaller since the ventilation ducting is smaller, and the number of auxiliary fans was cut by half or more," he said. "In addition, we avoided the need to develop a return air raise in the mine, which probably would have been very visible from the lake in winter due to the condensation plume."

A transition away from diesel-powered vehicles to electric-powered vehicles is likely to reduce ventilation requirements all over the world, as Hugo Dello Sbarba, **Howden**'s Ventsim™ – Director, explained.

"Conventional systems with diesel require you to push a lot of air into the stope/area during operations," he said. "With electrification, you will be able to reduce that volume of air to a much lower level."

Javier Fernández, Managing Director of **Zitron** Australia, added to this.

"The minimum amount of fresh air required for mines with 100% electric vehicle/equipment fleets, will not be calculated by reference to a certain ratio of air flow per kW of diesel engine, as is done today with the use of diesel-powered machinery," he said.

Yet, as everyone in the industry is pointing out, that does not mean mines will require no ventilation. Far from it.

"Mines will still have to clear blast fumes," Dello Sbarba told ***IM***.

Just as diesel particulate matter is dangerous for those working underground, so too are the fumes that come from blasting operations. This is why mines have numerous environmental monitoring stations in place to ensure miners return to the face when these fumes have dissipated.

The speed of return is dictated by the blasting practice itself, the accuracy of the environmental monitoring station and just how quickly and effectively the mine can clear the fumes with the ventilation system in place.

The ventilation applications of electric mines will not end with blast fumes.

David Ballantyne, Vice President of Product Development and Co-founder for **Maestro Digital Mine**, explained: "The focus in electric mines will shift from monitoring diesel emissions to monitor strata gas emissions, dust and heat."

Michael Gribbons, VP and Co-founder for Maestro, added to this: "Mines are getting deeper and are having to deal with higher strata temperatures and relative humidity.

"Worker heat stress is becoming a constraint to production and large, expensive chilling plants are required to bring the working zones into compliance."

Fernández thinks this focus on worker heat stress and the deepening of mines across the industry could in fact lead to larger volumes of fresh, ventilated air being required in all-electric mines

"When operating at deeper levels, the worker heat stress will be one of the key parameters for determining the amount of time that a miner can stay at the workplace, and ever larger volumes of fresh air and mine refrigeration systems will be required."

He added: "The increased use of new electric equipment provides us with a good opportunity for maximisation of productivity and, at the same time, lowering of energy costs.

"Electric motors are significantly more efficient

than their equivalent diesel engines. The diesel engine efficiency is typically around 33%, while electric motors are typically around 95% efficient. However, it is important to bear in mind that the ventilation requirements for a battery-electric mine does not completely follow the same electric-diesel efficiency ratio."

A mixed bag

For all the talk of electric-powered machines coming into the underground mining space, the reality today is that fleets are still made up of both diesel and electric equipment – the former outweighing the latter.

The same is the case for automation and teleremote operations, with different mines having more automation than others. This diversity of operator can also be seen within one mine itself as certain areas of manned mines are cordoned off for autonomous-only work.

It is such diversity that requires a sophisticated mine ventilation distribution and monitoring system.

"You will have mixed fleets for a long time – both diesel and electric vehicles will be there," Nyqvist said. "That provides the opportunity to distribute the air depending on where the different vehicles are. As a result, I see a bigger need in the future for a good, sophisticated ventilation system."

The ability to integrate with tagging, tracking and dispatch systems from mining equipment will be pre-requisites for these mine ventilation and monitoring systems.

Ouimet, referencing SHYFTinc's own NRG1-ECO energy management solution, provided an example.

"Our system can recognise the size of engine on each machine, as well as what it is discharging into the stopes," he said. "You can do that by using the machine tracking analytics, or through the environmental air quality monitoring station."

In transition

According to Dello Sbarba, Howden was quick to realise the industry was moving towards a future where ventilation control, not ventilation volume, is becoming the most important criteria.

"This is why Howden bought Simsmart, who are leaders in ventilation on demand (VoD) systems," he told ***IM***. "We saw this shift in the industry and were proactive in realising that we had to offer not only the steel (fans) to our clients, but the full solution."

The addition of Ventsim from Chasm Consulting in 2017 enabled the company to use the model as a tool to improve and test the controls implemented where Ventsim CONTROL was born. The model gives the company the ability to understand and predict how the controls will react in any situation whether it is for emergencies, blast clearing, excessive contaminants, cooling etc, Howden says.

"There is definitely a shift in the market and that is being catered for with our total mine ventilation solution strategy where we offer full turnkey ventilation solutions from the mine engineering all the way through to the equipment supply of fans, cooling systems, heaters and, of course, the controls and all of the instrumentation that comes with that," Dello Sbarba explained.

Other companies in the ventilation field were also prepared for this transition, one such firm being Maestro.

Maestro's market ambitions are far greater than the mine ventilation space, as Gribbons points out.

He told ***IM***: "While we started in the ventilation field, our domain expertise remains in the IIoT (Industrial Internet of Things) and digital networking space."

Despite this, Maestro has gained a reputation for providing ventilation control and environmental monitoring solutions that are ready to cope with the diversities of today's and tomorrow's underground mines.

This is backed up by the fact its Vigilante AQS™ (air quality station), which was introduced less than eight years ago, is in use at over 135 operations in 27 countries. Last year, it increased that market penetration with the introduction of its Zephyr AQS™ product.

Both are compact, environmental AQSs for underground mines, but Vigilante is seen as a holistic solution that can solve 100% of the applications for mine ventilation monitoring and control. Zephyr, meanwhile, is designed for 75% of the applications – such as airflow rate, airflow direction, gas levels, barometric pressure, and wet/dry bulb temperatures.

Gribbons and Maestro expected to capture the mid-tier and smaller mine operators with the introduction of Zephyr but, a year after launch, both have been surprised by the market uptake.

"Originally, we thought it would be a hit in Africa and Latin America, but when it was launched, it opened up applications with both our existing mining clients and those that could not originally afford the Vigilante AQS," Gribbons said.

Large global miners like Vale, Rio Tinto, Barrick Gold and Newmont all saw the value in bolting on a Zephyr unit to their existing mine infrastructure, realising it could be easily integrated with other Vigilante units and could be funded through their existing budgets.

In terms of ventilation and environmental monitoring requirements, Gribbons sees steady demand from the mining market, even with the increasing take-up of battery-electric equipment.

"We have witnessed as many environmental monitoring stations in all-electric mines as we do in regular mines," he said, referencing the company's work with Borden specifically.

But Gribbons does see changes coming, which Maestro is prepared for.

"With the on-coming electrification of mobile fleets, the next additional environmental or ventilation constraint will be dust," he said.

This belief has led the company to invest R&D dollars in a new compact dust sensor that can monitor both the dust particulate matter (PM) size and the dust loading, satisfying regulatory and worker safety concerns.

"We are currently Beta testing the new DustMon PM sensor at a Vale mine now. The new sensor can be added to any existing Vigilante or Zephyr AQS similar to that of our gas sensors," he said. "It is an economical, plug and play, IIoT device."

Gribbons says an air sample is drawn through the sensor and a laser counts the PM and groups the particles by size.

"The on-going testing will provide data on how often the sensor will need to be serviced in a dusty ramp application," Gribbons said. "We expect this to go into full production by September or October 2020 if no further modifications are required from a mechanical standpoint."

Powering up

Maestro's R&D does not end there.

Its Vigilante AQS is also being revamped to cope with increased requirements from mining companies, Gribbons said.

"After clients began to implement our Vigilante stations, they would often come back to us with new ideas," he said. "At a certain point in time, the horsepower under the hood could not cope with all of these new applications and ideas."

Ballantyne expanded on this: "We're going to use that increased horsepower to improve the number of different communication protocols we can support.

"We have basically rethought how we will configure standard, generic type input/output applications with it."

Maestro's Vigilante AQS is in use at operations owned by 17 of the top 20 mining companies in the world

This fourth generation platform will allow full automation of ventilation doors, regulators and sumps without the requirement of adding programmable logic controllers (PLCs).

"PLCs require cabinets, drawings, wiring, fabrication and integration, leading to high end-to-end costs, and then need to be maintained by specialists," Gribbons said.

"Maestro's product strategy is to eliminate expensive hardware, integration and engineering services by designing mine-hardened, application-specific IIoT digital solutions. It doesn't make sense to continue to use outdated technology just because it was done that way in the mid-70s.

"Many of our clients are already using Voice-over-IP phones so they understand the value from this technology and what we are doing is the same – providing a vastly less expensive integration, quicker and with full data and diagnostic functions."

It is developments such as this that distinguish Maestro's outlook on ventilation from its competitors.

As Gribbons neatly sums up: "A 10% productivity improvement trumps a 10% reduction in energy."

The onset of automation and digitalisation is allowing ABB to strengthen and power up its own VoD offering.

Its systems can be configured in three implementation levels depending on customer requests:

- Centralised supervision and control of ventilation equipment from ABB Ability™ System 800xA Operator workplaces;
- A full-scale VoD solution with automatic control of the ventilation equipment according to actual demand; and
- Mine ventilation optimisation using sensor feedback and advanced multivariable control technology to perform mine-wide control and optimisation of air flows and air quality while minimising energy consumption in real time.

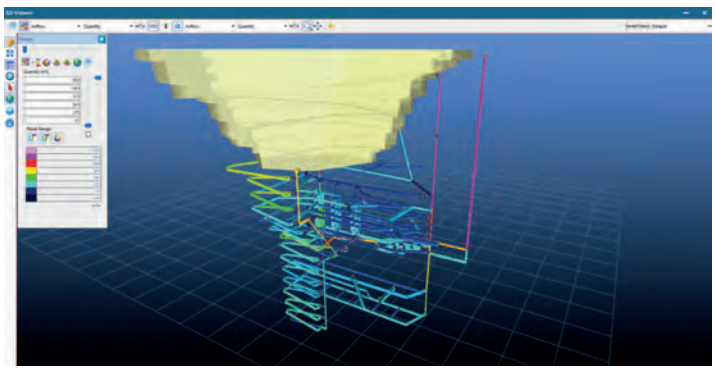
The company does not get involved in providing the ventilation fans for such systems, but it can carry out the engineering to ensure said fans are put in the right place and are informed with the correct data to run optimally.

"One of the things we see coming into the industry is more sensors," Nyqvist said. "That is another source of information we can use. This can be air volume flow sensors, sensors to measure temperature, etc."

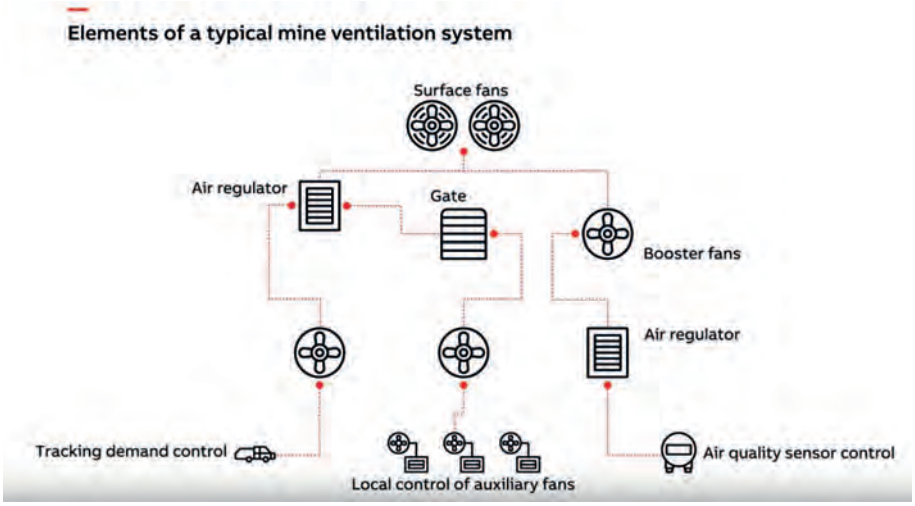
The increased number of sensors around mine sites and the improvement in network connectivity can boost a VoD system's accuracy.

"When you have both of these in place, you can start to communicate with the machines to make the system even more efficient – not only knowing where the machines are and the working time on the machine, but the speed of the machine," he said.

Incorporation of data from mine dispatch systems will improve the accuracy once again – allowing the system to ventilate an area ahead of a machine arriving to the area as opposed to when it is already in position. Both ABB and SHYFTinc are working on this integration, while Dello Sbarba says Ventsim CONTROL's Level 4 VoD



Ventsim CONTROL allows engineers to understand and predict how the controls will react in any situation whether it is for emergencies, blast clearing, excessive contaminants, cooling etc, according to Howden



The increased number of sensors around mine sites and the improvement in network connectivity can boost a VoD system's accuracy ABB says

system can already incorporate dispatch information.

Such machine and system data allows companies like ABB to create data-driven models to improve the optimal operating points of a ventilation system, according to Nyqvist.

"You always want fans and air regulators operating at the optimal speed," he said. "We can now use an algorithm to calculate that and use sensors for feedback on how well the system performed in that setup."

To do this, "the system collects the demand from gas sensors, or the tagging and tracking systems of vehicles and people, and matches this by calculating the optimal operating point of the fans and regulators", Nyqvist says

In big installations such as Codelco's Chuquicamata Underground mine – where ABB has installed 250 air quality sensors – this is a substantial amount of data to integrate.

"We push that data back to the system as set points and then record the performance with the flow sensors," he said. "We check the performance every 15 seconds to ensure the system is working optimally all the time."

These algorithms are generated from either past operating data or a modelling process conducted by ABB engineers.

Such processes require huge amounts of processing data and cannot be carried out with traditional control systems, according to Howden's Dello Sbarba.

"Developing mines will often go for a homegrown solution with a SCADA system," he said. "The difference between these SCADA systems and our solution is that a SCADA system is limited by the number of hours and programming you can put in it. Our system is specifically tailored for the application of underground mine ventilation meaning the possibilities are endless."

Highly leveraged

"It's the flexibility and scalability of NRG1-ECO that really differentiates it," SHYFTinc's Ouimet says. "You can implement it as an end-to-end complete process change, or you can implement it as a scaled setup where you are doing minimal work to start with."

The levels of ventilation control are part of this flexibility.

NRG1-ECO can offer mining companies anything from manual real-time control that allows them to manipulate devices through a web interface; time-of-day scheduling to automatically adjust devices at specific times; event-based planning where devices can be stopped/started or adjusted based

The fan blade and turning vane design is at the heart of the performance of an axial fan, with the fan's "character" determined by how these two components are designed and interact, Zitron says. Should a failure occur on an axial fan, the cause would most likely be the fan blades or the motor (mostly bearings).

The blade is also the most mechanically stressed component in the fan assembly, having to endure thousands of cycles at huge centrifugal forces.

Fan blades have been cast (sand cast mostly) for more than a hundred years and are still being successfully manufactured this way due to the ability to produce large quantities of components economically and without the need for many additional manufacturing steps.

But blade casting is by its very nature fraught with inherent obstacles, with testing of these blades – both destructive and non-destructive – showing numerous defects. These defects may cause catastrophic failure if not 'caught' during the quality control phase.

Zitron has recently invested in a custom designed 5-Axis CNC machine centre, dedicated solely to the development of new fan blades, and machining of operational/production primary fan blades.

The advantages this technology offers Zitron are numerous and far reaching, according to the company.

"It gives Zitron the capability to design, develop and test new fan blade profiles in a much shorter timeframe and at much lower cost than previously possible," the company said. On top of that, there is no need for patterns and moulds to be made for each new blade design, meaning much more intricate shapes and dimensions not previously possible through casting can be designed.

New blade profiles are designed using ANSYS and NUMECA CFD software specific to the fan's required duty. These blades are then machined in a matter of days, ready for testing in the actual fan it would be installed in, at the Zitron Test laboratory.

Another shortcoming of the casting process is the availability and consistency of castable materials, Zitron said. "With Zitron's machining capability, blades can now be manufactured from virtually any available, machinable material on the market."

The use of forged, high performance alloys, combined with the capability to control dimensions to within microns, results in blades having superior mechanical properties (tensile and yield strength), greater structural integrity and being lighter than comparative blades cast from other materials, according to Zitron.

Lighter blades result in lower centrifugal forces acting on the fan rotor, which in turn negate the requirement for heavy rotors. The rotating component (rotor and blades) ends up having a lower inertia and mass also. Bearing life is extended as a result, reducing maintenance costs.

"Another advantage is the superior surface finish that a machined blade has over one that is cast," Zitron said. "There is no need for polishing after casting, which is another action that can introduce problems such as stress raisers in critical areas when polishing is not performed with the correct equipment and with due care."

Due to having identical dimensions, machined blades also weigh the same for a specific shape. Blades, therefore, do not require weight sorting for dynamic balancing purposes.

While Zitron says this new process will not replace cast blades in the majority of the fans supplied, it will add to the existing technological advances made and used by the company.

on an operational or programmed event; environmental control where the system responds to environmental sensor networks inside the mine; or tagging (activity-based) control, which integrates with new or existing real-time location systems to deliver the required air flow based on personnel or vehicle locations in the mine.

The open architecture of NRG1-ECO, which is now in its fifth generation, allows the system to connect with operating systems already up and running at these mines, according to Ouimet.

"At any point in time, there are several air quality monitoring companies in the industry and our NRG1-ECO software can work with any of them," he explained. "The integration with machine tagging sensors and systems is similar."

The hardware and software of NRG1-ECO leverages off these existing technologies and sensors to do more than just control ventilation.

Ouimet explained: "We won a contract where the NRG1-ECO became the energy optimisation system of choice for all Vale's North Atlantic operations.

"Most people think of that as a ventilation control system and VoD, but NRG1-ECO will monitor and control dewatering pumps, compressors, etc – any of the energy drivers of a mine."

SHYFTinc's sister company, **BESTECH Engineering**, developed and still supports the NRG1-ECO platform. The BESTECH electrical and automation engineers – all of whom thoroughly understand a mine's energy consumption requirements – are able to complete detailed analysis of how to reduce a mine's costs over the long term, according to Ouimet. This is then embedded into the NRG1-ECO installation for that specific site.

These same mining customers can also benefit from using artificial intelligence-assisted code authoring through SHYFTinc's AutoGen platform. AutoGen takes control of their processes and devices by integrating all equipment – regardless of vendor – into one platform.

Ouimet explained: "A mine can set up and manage their processes through a simple drag and drop interface using this industrial plug and play technology."

The company is looking to use its mine energy knowledge by recycling some of the energy that is currently generated in mines but goes unused. It recently signed an agreement with Rentricity that could see in-pipe power generation systems installed on gravity-fed piping in underground or open-pit mines.

"You can implement NRG1-ECO as an end-to-end complete process change, or you can implement it as a scaled setup where you are doing minimal work to start with," Randy Ouimet says

Ouimet explained: "In a mine, you may have 5,000 ft (1,524 m) of pipe and water is moving down that at high pressures. Instead of dissipating that energy to heat, we are talking about taking that energy and turning it into power to be used for other processes or sold back to the grid through in-pipe power generation systems.

"You could end up having 15-200 kWh systems in place," he said.

Tailored air time

While companies like SHYFTinc, ABB and Maestro are diversified in other fields tied to automation of operations, they are unlikely to leave the field of ventilation altogether.

This is because underground ventilation continues to account for around 50% of operating costs for miners. This is a large chunk of the opex pie to aim for, hence the potential for making a real difference when it comes to miners' bottom lines.

This does not appear to have hit home with a lot of in-development mines by the sound of it, with many continuing to invest in fans and vents that run at full speed and capacity regardless of what activities are going on in the mine.

"There is a lack of understanding when it comes to doing the right thing with mine ventilation from the very beginning of operations," Nyqvist said.

Dello Sbarba said the short-term thinking exhibited by contractors in charge of building these mines is often the problem.

"When a mining contractor is in charge of ventilation, it is a much harder sell," he said. "If the actual miner in charge of ventilation is provided with this information, they often realise that the gains could be significant over the longer term.

"Saying that, the upfront capex can often prove to be a hurdle, which is why we have developed financial solutions with our clients to overcome these challenges."

Spending a little bit more upfront for the longer-term benefit of the operation will become more important as the uptake of electric equipment grows – again, equipment that currently comes with a bigger price tag than the diesel-powered equivalent.

And, so it will end up becoming just another capex versus opex discussion.

What will undoubtedly change going forward is the ability and need to tailor mine ventilation solutions.

By scrapping conventional thinking around ventilating for diesel tail pipe emissions, those in the ventilation game will be asked and able to create customised solutions that not only save operating costs, but also enable maximum productivity in a variety of situations.

Fernández concluded: "Each mine should be analysed individually. With increasingly deeper operations required, mining ventilation systems will have to cope with higher rock temperatures, increased air densities and other challenges. Doing so will demand fully understanding the capabilities of a ventilation system, as well as real-time monitoring of the conditions in the work environment." IM