STONE MINE VENTILATION

Brian Prosser, PE

Principal Consultant, SRK Consulting

Introduction

Brian Prosser, PE is a Principal Consultant with SRK Consulting with over 20 years of ventilation experience. He has conducted studies for both hard rock mines and coal mines throughout the world. He has developed both climatic simulation models for deep mining operations and fire simulation models to assist in the planning of the health and safety aspects of mine designs. He has been involved with numerous studies for limestone, salt, repositories, and mines with large openings. He is a graduate from Virginia Polytechnic Institute and State University with a Bachelors Degree and is a licensed professional engineer in Nevada, Kentucky, and Virginia.

Common Definition

MINING ACADEMY
Improving Processes. Instilling Expertise.

Why do we ventilate mines?

- ***The objective of underground ventilation is to provide airflows in sufficient quantity and quality to dilute contaminants to safe concentrations in all parts of the facility where personnel are required to work or travel. (McPherson)***
- ***This issue is about <u>health and safety</u>***
- ***Ventilation is often seen as just a cost***

Commonality Among Stone Mine Ventilation Systems

- *Large openings*
- *High volumes of airflow*
- *Large equipment (high power requirements)*
- *Low frictional pressure losses*
- *Dust*
- *Crushers*

Differences Among Stone Mine Ventilation Systems

- ***Equipment loads are different***
- ***Orientation of portals***
- ***Surface topography, shafts, portals***
- ***Strata gas, local environmental concerns***

There is no cookie cutter design



Ventilation Plan (30 CFR 57.8520)

MINING ACADEMY
Improving Processes. Instilling Expertise.

(a) The mine name.

(b) The current mine map

(1) Direction and quantity of principal air flows;

(2) Locations of seals used to isolate abandoned workings;

(3) Locations of areas withdrawn from the ventilation system;

(4) Locations of all main, booster and auxiliary fans not shown in paragraph (d) of this standard.

(5) Locations of air regulators and stoppings and ventilation doors not shown in paragraph (d) of this standard;

(6) Locations of overcasts, undercasts and other airway crossover devices not shown in paragraph (d) of this standard;

(7) Locations of known oil or gas wells;

(8) Locations of known underground mine openings adjacent to the mine;

(9) Locations of permanent underground shops, diesel fuel storage depots, oil fuel storage depots, hoistrooms, compressors, battery charging stations and explosive storage facilities. Permanent facilities are those intended to exist for one year or more; and

(10) Significant changes in the ventilation system projected for one year.

(c) Mine fan data for all active main and booster fans

(d) Diagrams, descriptions or sketches showing how ventilation is accomplished in each typical type of working areas

(e) The number and type of internal combustion engine units used underground,

Calculate Airflow Requirements

MINING ACADEMY
Improving Processes. Instilling Expertise.

- *Diesel Equipment*
- *Shops/Garage/Fuel Bay*
- *Dust*

Airflow Calculation - Diesel

General dilution is used when the equipment list is unknown, general planning

This type of calculation is done for all of the equipment in operation in the mine

[1]CAT R1700 LHD Loader

[1]CAT AD30 Truck

- **CAT R1700 263 kW × 2 × 0.06 $m^3/s/kW$ = 31.6 m^3/s**
- **CAT AD30 305 kW × 1 × 0.06 $m^3/s/kW$ = 18.3 m^3/s**

- **Total Airflow for Level = 50 m^3/s**

Airflow Calculation – NIOSH/MSHA

Remember airflow for Particulate Index (PI) takes the concentration down to 1,000 µg/m^3 (DPM) or 800 µg/m^3 (TC), to reach 160 µg/m^3 (TC) multiply the PI times 5.

This type of calculation is done for all of the equipment in operation in the mine


[1]CAT R1700 LHD Loader


[1]CAT AD30 Truck

MSHA Web Site Approved Equipment List

				Dilution	PI
7E-B018	CATERPILLAR	3406E ATAAC	400 @ 2100	18500	13000

Truck – Diesel Dilution (gas) = 18,500 cfm (8.73 m^3/s),
DPM 5×13,000 = **65000 cfm (30.68 m^3/s)**

				Dilution	PI
7E-B018	CATERPILLAR	3406E ATAAC	360 @ 2100	17000	14000

LHD – Diesel Dilution (gas) = 17,000 cfm (8.02 m^3/s),
DPM 5×14,000 = **70000 cfm (33.04 m^3/s)**

Total Level Airflow (Diesel Dilution)– 8.73+8.02+8.02 = <u>24.77 m^3/s</u>

Total Level Airflow (DPM Dilution to 160)– 30.68+33.04+33.04 = <u>96.76 m^3/s</u>

§ 57.5067 Engines.

(a) Any diesel engine introduced into an underground area of a mine covered by this part after July 5, 2001, other than an engine in an ambulance or fire fighting equipment which is utilized in accordance with mine fire fighting and evacuation plans, must either:

(1) Have affixed a plate evidencing approval of the engine pursuant to subpart E of Part 7 of this title or pursuant to Part 36 of this title; or

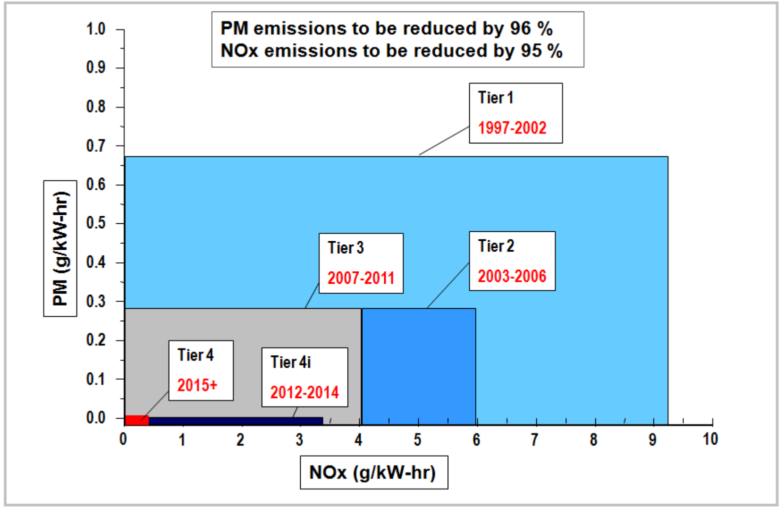
(2) Meet or exceed the applicable particulate matter emission requirements of the Environmental Protection Administration listed in Table 57.5067-1, as follows:

EPA requirement	EPA category	PM limit
40 CFR 86.094-8(a)(1)(i)(A)(2)	light duty vehicle	0.1 g/mile.
40 CFR 86.094-9(a)(1)(i)(A)(2)	light duty truck	0.1 g/mile.
40 CFR 86.094-11(a)(1)(iv)(B)	heavy duty highway engine	0.1 g/bhp-hr.
40 CFR 89.112(a)	nonroad (tier, power range)	varies by power range:
	tier 1 kW<8 (hp<11)	1.0 g/kW-hr (0.75 g/bhp-hr).
	tier 1 8≤kW<19 (11≤hp<25)	0.80 g/kW-hr (0.60 g/bhp-hr).
	tier 1 19≤kW<37 (25≤hp<50)	0.80 g/kW-hr (0.60 g/bhp-hr).
	tier 2 37≤kW<75 (50≤hp<100)	0.40 g/kW-hr (0.30 g/bhp-hr).
	tier 2 75≤kW<130 (100≤hp<175)	0.30 g/kW-hr (0.22 g/bhp-hr).
	tier 1 130≤kW<225 (175≤hp<300)	0.54 g/kW-hr (0.40 g/bhp-hr).
	tier 1 225≤kW<450 (300≤hp<600)	0.54 g/kW-hr (0.40 g/bhp-hr).
	tier 1 450≤kW<560 (600≤hp<750)	0.54 g/kW-hr (0.40 g/bhp-hr).
	tier 1 kW≥560 (hp≥750)	0.54 g/kW-hr (0.40 g/bhp-hr).

Airflow Calculation – Air Quality

Airflow for dilution for diesel exhaust (gasses) is a requirement, PI is a guide.

- Reducing DPM is critical, in addition to dilution, other methods exist.
- Tier 4 equipment
- After treatment exhaust devices
- Clean fuel (low sulfur)
- Improved maintenance
- Enclosed cabs are Good, but not all People are in cabs

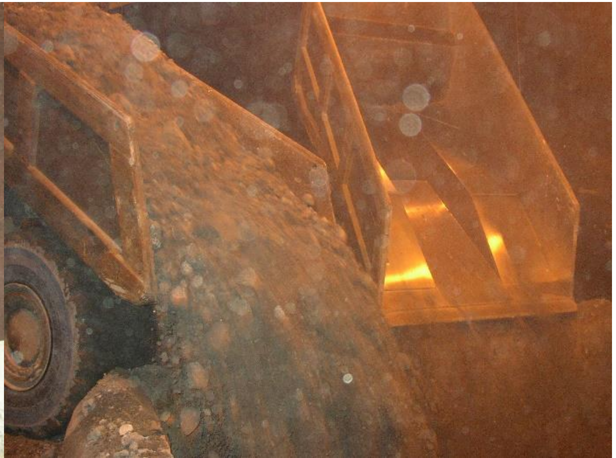


Specific Areas

- Crushers, Shops, Conveyors

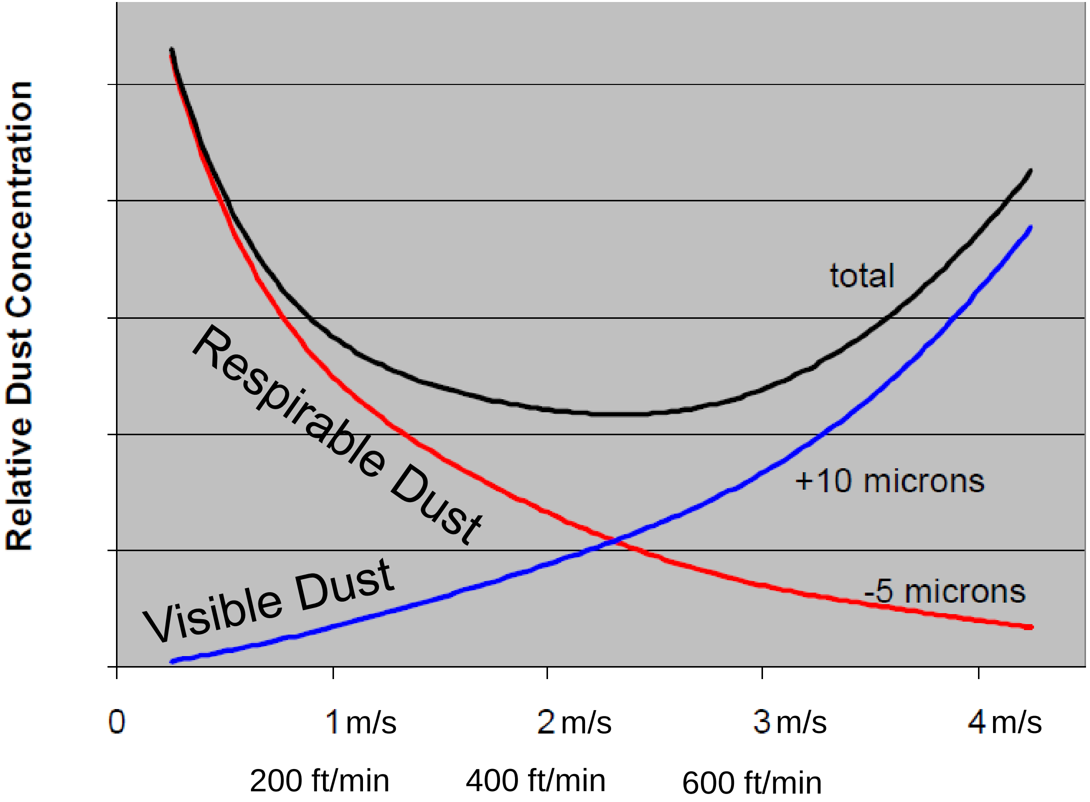
Crushers

- *Large openings*
- *High Dust Concentrations*
- *Route the airflow directly to the mine exhaust*
- *Place workers in control booths (filtered/positive pressure)*



Air Velocity and Dust

With too little air the dust will just hang in the air and will not clear, with too much the dust will re-entrain



How fast do you really want to move air along a dusty airway?

Shop, Fuel Bay, Garage Ventilation

- Example Air Change Rates
- Assumptions are built into rates like welding fume hoods, hookups for diesel exhaust extraction at tailpipe.

Location	Minutes per Air Change
Training Room	6
Offices	5
Warehouse Areas	7
Electrical Room	6
Service Bay	3
Sanitary Facilities	5
Lunchroom	5

(ASHRAE)

Airflow Calculation Based on Air Change Rates

Location	Area Dimensions (m)			Minutes per Air Change	Volume (m^3)	Airflow (m^3/s)	Number of Areas	Total (m^3/s)	Total (kcfm)
Office	5	5	60	5	1500	5.0	3	15.0	**31.8**
Training	5	5	60	6	1500	4.2	2	8.4	**17.8**
Warehouse	7	6	80	7	3360	8.0	2	16.0	**33.8**
Service Bay	7	6	40	3	1680	9.3	6	18.6	**39.4**
								58.0	**122.9**

- Contaminants directed to exhaust at point of origin
- Fans can be used to provide localized flow direction
- Fuel Bays and lubricant storage areas should be directly exhausted (isolation or fire doors)

Fuel Bay

MINING ACADEMY

Improving Processes. Instilling Expertise.

- Establish Minimum Velocities
- Use air changes for airflow evaluation
- Discharge or exhaust location
- Isolation doors
- Fire suppression

Conveyors

Conveyors

- Airflow should move in the same direction as the conveyor belt (homotropal).
- Antitropal flow can be achieved but it should be designed to minimize dust (water, moisture content, covered conveyor, dedicated conveyor exhaust).
- As we move away from homotropal flow additional features must be designed into the system.

MINING ACADEMY
Improving Processes. Instilling Expertise.

Note.
Conveyors generally move rock out of the mine, which means that the air source for the conveyor is additive to the overall ventilation load, unless exhaust air is used

Moving Air Around

- Main Fans, Boosters, Curtains, Pillars

MINING ACADEMY
Improving Processes. Instilling Expertise.

Ventilation Controls

- Main fans
- Booster fans (jet fans)
- Curtains/Bulkheads
- Pillars

Main Fans

- Main fans are responsible for getting airflow into and out of the mine.
- The operating pressure of the main fans is most influenced by their installation and any constrictions (shafts or pinch points)
- For stone mines generally they consist of high volume/low pressure installations where shafts are not required (shafts typically account for 90% of system resistance/pressure)

Efficiency

Efficiency can be increased with the addition of inlet bells and discharge cones

- Exit loss is equal to a direct loss of kinetic energy, or the velocity pressure.
- For this loss to be minimized the velocity needs to be minimized, this is why we use a discharge evasé (to minimize the discharge velocity/velocity pressure).

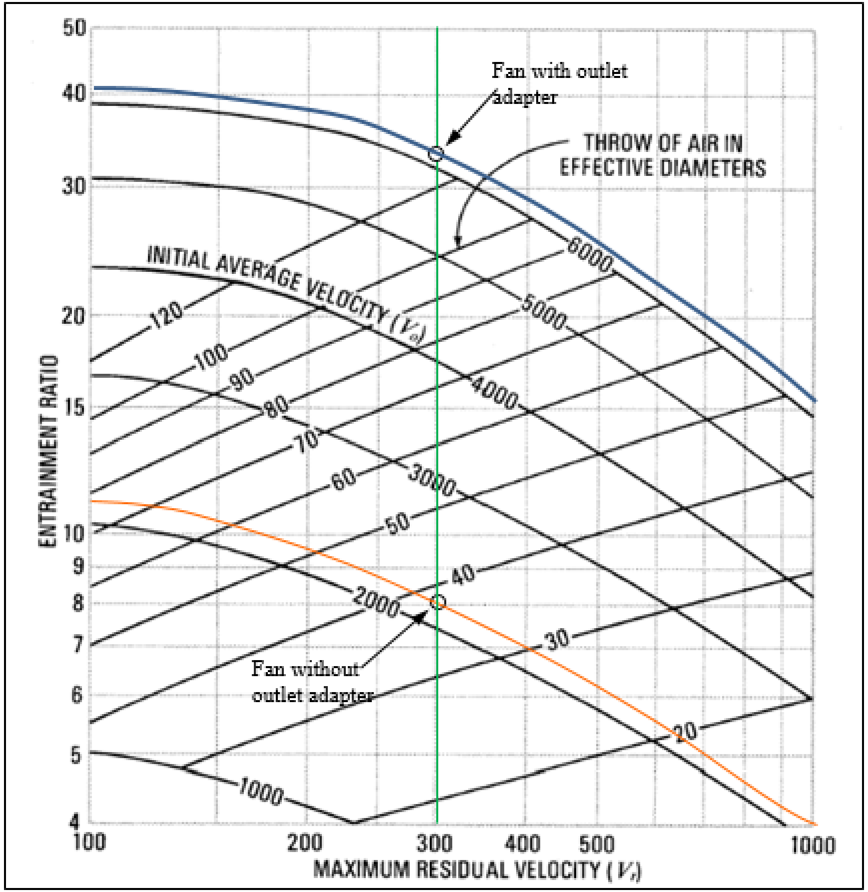
- Inlet without bell has a Shock Loss Value of X =1.0
- Inlet with bell has a Shock Loss Value of X=0.03

Booster Fans

- Booster fans are used to provide circulation through the ventilation system
- Curtains and bulkheads are not always possible
- Airflow can be directed along haulage routes and through areas where personnel are located
- Jet fans are a type of booster fan

Jet Fans

- **The addition of reducer at the end of a freestanding fan can greatly increase the effectiveness of the fan**



Jet Fans

Jet fans typically provide an effective ventilation pressure ranging from 0.060 to 0.100 in. w.g. (15 to 25 Pa).

Thrust = Tunnel Area x Pressure

where	T = thrust (N) A = tunnel area (m^2) P = pressure (Pa)

Velocity = SQRT Thrust/air density x outlet area

where	V = velocity (m/s) T = thrust (N) ρ =air density (kg/m^3) a = outlet area of fan (m^2)

MINING ACADEMY
Improving Processes. Instilling Expertise.

Curtains, Bulkheads, Pillars

- Separation is required between fresh air courses and exhaust air courses
- This is required to minimize recirculation
- To provide positive ventilation to working areas
- To provide routing of air through shops and facilities

Curtains

- Curtains spread over large cross-sections cannot resist significant pressure differentials
- Equipment passing in front of curtains can cause curtains to become disrupted and leaky
- It is possible to pile muck in cross-cuts and install curtains at the top of the piled muck so that shorter curtains can be used.

Bulkheads

- Bulkheads can resist a significant differential pressure
- They can be expensive to install
- They should be used around shafts, portals, shops, or other fixed locations

Long Pillars

- If the mining plan can be established well in advance then pillar lines can be developed
- For long pillars, cross-cuts are developed, but not holed through all the way.
- These act as “bulkheads”

Ventilation Modeling

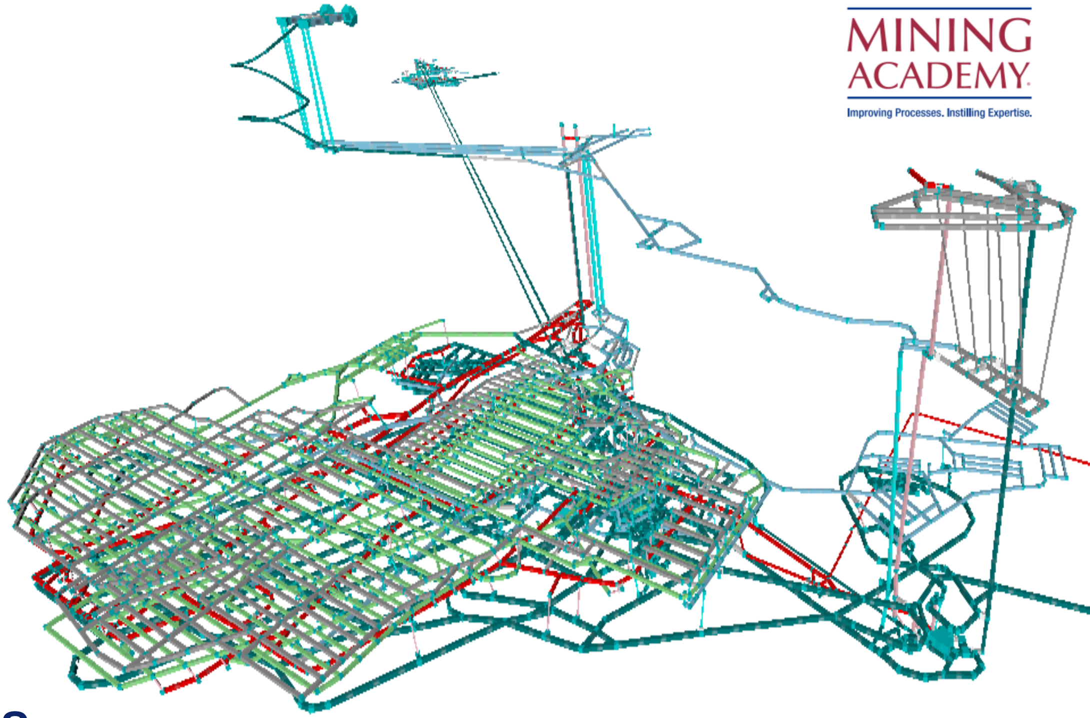
- Examining the ventilation system by modeling

Ventilation Modeling

- Ventilation Models can be used to examine the ventilation system
- The interactions between different mining areas can be examined
- Fan operating points can be established
- The placement and interaction of booster and jet fans can be evaluated

Ventilation Modeling

- With the software packages available today large changes in the ventilation systems should be modeled or previewed to identify potential pitfalls.
- New ventilation systems should be modeled
- Why take a chance on missing a resistance, miss calculating, or guessing.

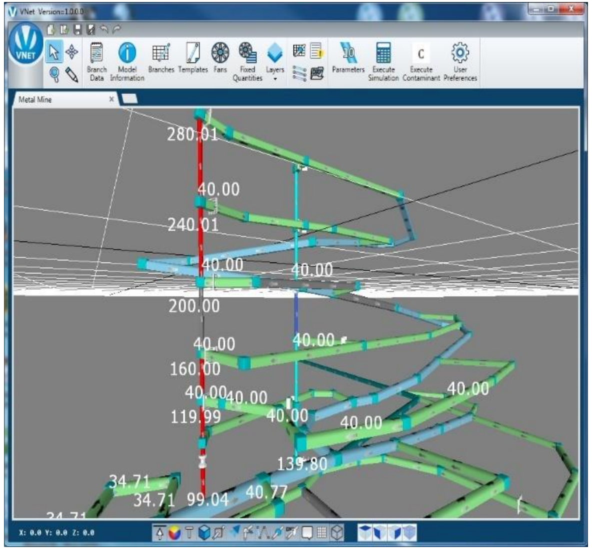


MINING ACADEMY
Improving Processes. Instilling Expertise.

Relationship Between Mining Area Values and Total Mine Airflow

Ventilation Modeling Software is Used to Establish These Models:

- VnetPC,
- VentSIM,
- VUMA, etc.



- First - identify the area or level ventilation requirement
- Second – apply that value to all the active levels in the mine and use ventilation model to identify system infrastructure

Ventilation Modeling – General Layout

- There is no general cookie cutter ventilation design.
- Leakage
- How does air get into the mine and out of the mine
- How can curtains or separations be achieved, what resistance is required
- How fast can the air be circulated through the ventilation system (build up of NO_2)

Questions and General Discussion

Clovis California Office

1625 Shaw Ave Suite 103

Clovis, CA 93611 U.S.A.

(559) 452-0182 phone

(559) 452-0184 fax

bprosser@srk.com

Mine Ventilation Services, Inc.
A New Business Unit Of

References

- Fytas, K. and Gagnon, C., 2008. <u>A Database of Ventilation Friction Factors for Quebec Underground Mines</u>, *Proceedings of the 12th US/North American Mine Ventilation Symposium*. Pp 615-622 (University of Nevada, Reno).
- Duckworth I.J, Loomis I, Prosser B. 2012. <u>Fifteen Years of Resistance Data Collected at Freeport Indonesia</u>, *Proceedings of the 14th US/North American Mine Ventilation Symposium*, pp 161-166 (University of Utah)
- Prosser, B.S., Wallace, K.G., 1999. <u>Practical Values of Friction Factors</u>, *Proceedings of the 8th US Mine Ventilation Symposium*, pp 691-696 (University of Missouri-Rolla Press)
- McPherson, M.J., 2009. *Subsurface Ventilation and Environmental Engineering*, (Mine Ventilation Services, Inc. California USA) ISBN: 978-0-692-00024-3
- Vutukuri V.S., Lama R.D., 1986. *Environmental Engineering in Mines*, Cambridge University Press, London, ISBN: 0-521-24605-9
- Jorgensen, Robert. 1999. Fan Engineering. Howden Buffalo, Inc. Buffalo, New York

MINING ACADEMY
Improving Processes. Instilling Expertise.

srk consulting

MINING ACADEMY®

Improving Processes. Instilling Expertise.

DYNO®
Dyno Nobel

SANDVIK