Auxiliary Ventilation: Good Installation and Maintenance Practices for Miners

Workplace Safety North™

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Auxiliary Ventilation: Good Installation and Maintenance Practices for Miners. First publication

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Auxiliary Ventilation: Good Installation and Maintenance Practices for Miners

1. Introduction

In hard rock mines there are various methods for supplying ventilation to the underground work areas. Several common mistakes are often made or overlooked, which lead to inefficient or ineffective ventilation systems. The intent of this document is to focus on the auxiliary ventilation systems that provide air directly to the face, highlight some common examples of mistakes made and provide simple and practical solutions for employees and frontline supervisors in order to effectively utilize available ventilation air.

Workplace Safety North (WSN) and the Workplace Environment Technical Advisory Committee (WE TAC) believe the topic is relevant and timely considering the recommendations of the Mining Health and Safety Prevention Review (MHSPR). Ventilation is an important control strategy for occupational disease prevention in underground mines.

WSN recognizes that individual companies must develop health and safety policies and programs which apply to their workplaces and comply with appropriate legislation. The information contained in this reference material is distributed as a guide only to assist in developing those policies and programs.

2. Why It's Important – The Health Effects

The four main reasons ventilation is supplied underground are:

a. **To supply oxygen for breathing.**

Workers are required to work underground to carry out various activities during the mining cycle. These activities include: production, maintenance, development, construction, support services or logistical activities. Oxygen levels decrease as a result of these activities; thus ventilation is essential to sustain sufficient levels of oxygen for safe and healthy working conditions.

b. **To dilute and remove contaminants generated during the mining process (e.g. diesel powered equipment, material movement, ground support, maintenance activities, shotcrete and many others).**

Diesel engine exhaust is composed of particulate as well as a variety of gases (most commonly carbon monoxide, oxides of nitrogen). Silica dusts (naturally found within ore or waste rock) are classified as known human lung carcinogens by the International Agency for Research on Cancer (IARC). Maximizing the amount of volume and speed of air movement is critical for controlling these contaminants combined with other layers of control. The overall intent of these controls is to reduce worker`s exposure and risk for both acute health effects (things that can harm a person immediately) and chronic health effects (things that can harm a person years later such as an occupational disease).

Worker exposure to many other contaminants that may be generated during the mining cycle can also be reduced with a properly functioning ventilation system.

c. **To dilute and remove contaminants from blasting operations.**

Detonation of explosives generates various contaminants such as dusts, carbon monoxide, oxides of nitrogen and other gases. The acute health effects of exposure to these contaminants can be severely debilitating or even fatal. A well maintained ventilation system assists with reducing blast clearing times and reduces the risk for worker exposure to dusts and gases.

d. **To control and regulate temperature and humidity (which can result in heat stress conditions).**

The exchange of air allows for warm air to leave the work place and cooler air to enter it. Diesel powered equipment and characteristics of the mine such as depth and rock properties contribute a significant amount of heat to the working environment. Conditioning the air and maximizing the quantity and speed of air movement is critical for controlling heat stress related hazards, combined with other layers of control. Various factors are required to reduce the risk for heat stress related injury.

3. Why Mine Ventilation Issues Occur

There are a variety of factors that can cause inadequate air volume reaching the underground workplace. In most instances, the ventilation duct is in poor condition; basic ongoing maintenance of the auxiliary system is the solution. It is necessary for workers in the field to have the tools, equipment, knowledge, and materials available to them to be able to solve the ventilation deficiencies. In addition, front-line supervision has the responsibility to identify deficiencies and correct substandard conditions with workers in the field. Although these activities require time and resources, they are critical for ensuring a safe and healthy workplace. It is critical for this process to follow in line with the internal responsibility system.

The following are some additional considerations for ensuring proper installation and maintenance practices of auxiliary ventilation systems:

a. Establish standard designs for auxiliary ventilation installations.
b. Proper communication to Supervisors and Workers including providing training on how to install and maintain mine ventilation systems.
c. Establish inventory management for auxiliary ventilation supplies and accessories (e.g. tubing, fans, chain kits, silencers, inlet bells, etc.). Have designated storage areas with signage and restocking requirements to meet the demands of the mine.

4. Pertinent Legislation – Regulation 854 Mines and Mining Plants

The following are some sections of the legislation pertinent to mine ventilation taken from R.R.O. 1990, Reg. 854: Mine and Mining Plants made under the Occupational Health and Safety Act, R.S.O. 1990, c.O.1. When referencing the legislation, ensure to refer to the latest versions in R.R.O. 1990 Reg 854 (https://www.ontario.ca/laws/regulation/900854)

183.1 (1) The employer shall ensure that a flow of air that meets the requirements of this section is provided to the workplace where diesel-powered equipment is operating. O. Reg. 779/94, s. 7.

(2) The flow of air must be provided by a mechanical ventilation system. O. Reg. 779/94, s. 7.

(3) The flow of air must be at least 0.06 cubic metres per second for each kilowatt of power of the diesel-powered equipment operating in the workplace. O. Reg. 779/94, s. 7.

(4) The flow of air must reduce the concentration of toxic substances in diesel exhaust emissions to prevent exposure of a worker to a level in excess of the limits prescribed under section 4 of Regulation 833 of the Revised Regulations of Ontario, 1990 (Control of Exposure to Biological or Chemical Agents) made under the Act. O. Reg. 265/15, s. 11.

(5) The flow of air must,

(a) reduce the time-weighted average exposure of a worker to total carbon to not more than 0.4 milligrams per cubic metre of air; or

(b) reduce the time-weighted average exposure of a worker to elemental carbon, multiplied by 1.3, to not more than 0.4 milligrams per cubic metre of air. O. Reg. 296/11, s. 13.

253. (1) In an underground mine, a mechanical ventilation system shall be provided, maintained and used that will,

(a) provide an oxygen content in the atmosphere of at least 19.5 per cent by volume; and

(b) dilute and remove contaminants from all workplaces therein to prevent exposure of a worker to contaminants in excess of the limits prescribed under section 4 of Regulation 833 of the Revised Regulations of Ontario, 1990 (Control of Exposure to Biological or Chemical Agents) made under the Act. R.R.O. 1990, Reg. 854, s. 253 (1); O. Reg. 272/97, s. 47; O. Reg. 496/09, s. 3; O. Reg. 265/15, s. 15.

5. The good, the bad and the ugly

The following illustrations highlight the good, the bad and the ugly of auxiliary ventilation systems found in the workplace. It highlights some of the more common issues seen underground. Throughout, it should be noted that, the negative effects of poor connections, holes, blast damage, constrictions, abrupt expansions, abrupt bends, etc. increase in magnitude with their proximity to the fan as pressure is high at this distance.

This good practice document focuses on the installation, outcomes and solutions.

For further detailed information please refer to Workplace Safety North's Auxiliary Mine Ventilation Manual (https://www.workplacesafetynorth.ca/products/auxiliary-mine-ventilation-manual).

The Good – Auxiliary duct installation

Installation:

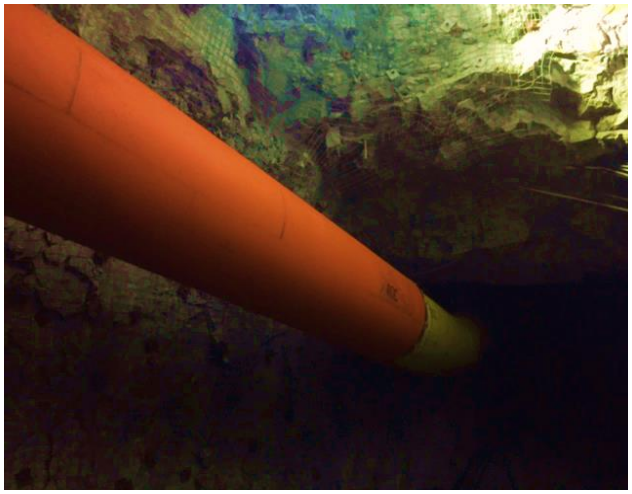
- Ducting is installed straight and level. This practice should be applied to every type of duct (e.g. steel, flexible, plastic, or fiberglass).
- Flexible duct must be hung from messenger cable that has been tensioned (but the tubing itself should be installed as straight as possible to minimize airway resistance).
- Rigid duct must be secured with chains and rabbit ears (could also apply to plastic and fiberglass ducts).
- Joints are properly connected to minimize leakage. The use of proper band for steel, fiberglass and plastics. Use of proper connector clips and zippers for flexible tubes.
- Install the correct number of connector clips for flexible duct based on its diameter.
- Rigid duct has less friction versus flexible or spiral duct.
- Dust should be installed as high to the back (roof) as possible to prevent contact with equipment.
- No holes or damage in the duct.

Outcomes:

- More air delivered to the work area (end of duct).
- Minimum air loss - less leakage and shock loss (shock loss is resistance in the airway, thus resulting in pressure loss).
- Ventilation ducting can be extended to its maximum designed distance due to its efficiency.
- Efficient system.

Solutions:

- Maintain condition of ducting through routine inspections.
- Ensure discharge end of the duct is at the appropriate distance from the face.



The Good – Auxiliary fan installation

Installation:

- Fan, silencers, ducting and accessories securely hung to prevent system from falling if contact is made by mobile equipment (as per the sites standard).
- Fan installed with proper accessories (e.g. inlet bell, protective screen, silencers on the inlet and outlet sides).
- Proper use of adapter to connect ducting to the fan.
- Duct properly coupled to the adapter.
- Fan is installed in a proper location which promotes efficiency and minimizes re-circulation. It is recommended the fan should be installed 10 m (33 ft) from access.

Outcomes:

- More air delivered to the work area (end of duct).
- Proper fan installation, set-up and design. Properly designed and installed accessories aid at improved fan efficiency.
- Silencer(s) significantly reduces noise.
- Minimum air loss due to proper installation practices.

Solutions:

- Maintain condition of fan system.

The Good – Brattice or curtain installation

Installation:

- Brattice or curtain installed tight to the back, sidewalls and floor.
- Brattice or curtain is properly stretched to avoid ballooning outward or inward.
- No holes or damage to the brattice or curtain.
- Spray foam to ensure an airtight seal.
- The seal material and seal design should be selected such that the expected pressure does not exceed the maximum rated static pressure, otherwise it will fail.

Outcomes:

- Minimum loss due to leakage.

Solutions:

- Maintain condition of brattices or curtains.

The Good – Smooth bend duct installation

Installation:

- Spiral wire reinforced ducting is installed on the bend of the heading in a smooth curved path.
- Use spiral duct of correct pitch depending on application (e.g. 6” pitch on the positive side).
- Ducting joints are properly connected to minimize leakage. The use of proper connector clips with enough clips on the outside portion of joints ensures this ducting will not come apart.
- Direction of ducting installation has the arrow on the spiral ducting pointing towards the face. This is very critical, as hanging the ducting backwards can restrict flows up to 40%.

Outcomes:

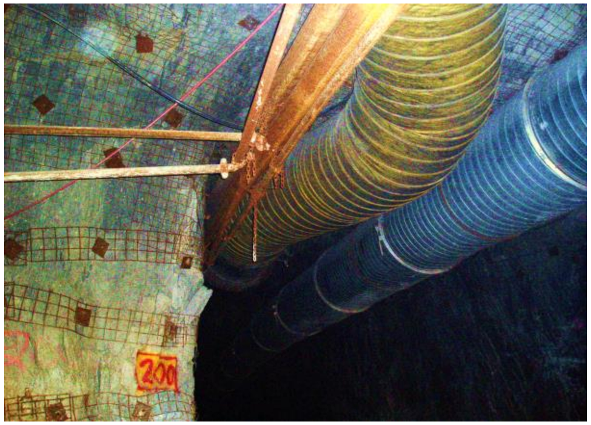
- More air delivered to the work area (end of duct).
- Efficient system, smooth curved path for the air to follow, which prevents shock losses to occur.
- Minimum air loss - less leakage and shock loss (shock loss increases resistance in the airway, thus resulting in pressure loss).
- Ventilation ducting can be extended to its maximum designed distance due to its efficiency.
- If lay flat ducting is used for bends it can create kinks restricting airflow causing shock losses. Abrupt bends in spiral duct also causes shock loss.

Solutions:

- Maintain condition of fan system.
- Utilize the proper type of ducting for the application.

Benefits:

- Increased airflow at the end of the ducting, therefore, provides further reduction of worker exposure to contaminants (healthier workplace).
- More efficient system, as less shock loss is produced and back pressure on the fan is reduced resulting in less kW’s of power used (cost savings).



The Bad – Auxiliary fan and duct installation

Installation issues:

- Connected larger (or smaller) duct diameter to the fan without proper adapter (as shown by the bulging of the duct).
- Abrupt change in airway diameter (reduced or expanded) causes turbulence that results in shock loss.
- Abrupt bends.

Outcomes:

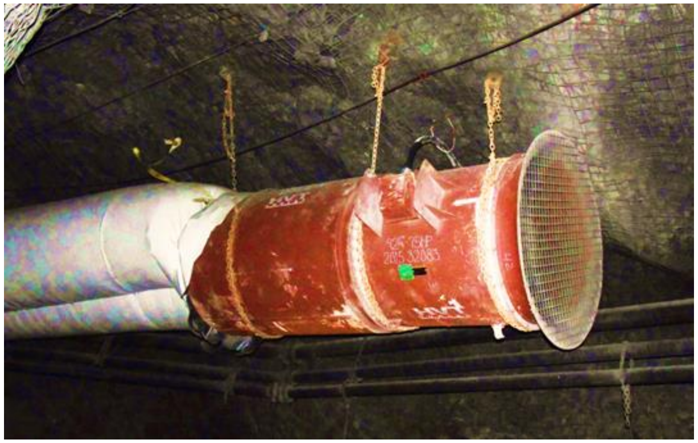
- Increased shock loss (due to turbulence). Note: there is higher air pressure experienced near the fan, which means a greater effect on the system.
- Increased leakage due to improper connection.
- High shock losses from the installation result in back pressure on the fan due to the proximate location to the fan, which reduces the volume or airflow from the fan.

Solutions:

- Proper use of diffuser or reducer to allow for a smoother transition and minimize excessive turbulence or shock loss.
- Utilize proper duct size for the fan diameter.
- Properly connecting joints with appropriate connectors to minimize leakage
- Proper alignment of fan and ducting.
- Check to ensure that the fan is designed to meet the needs of the system.
- Ask a ventilation engineer or specialist for other technical solutions.

Benefits of implementing the solutions:

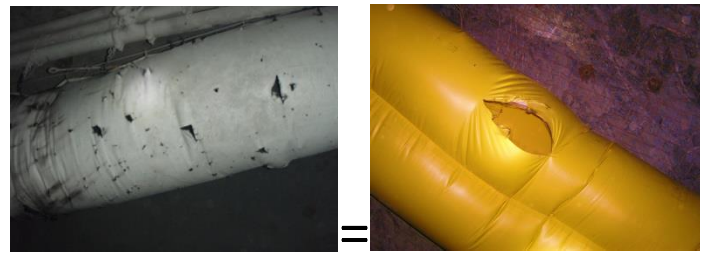
- Increased airflow at the end of the ducting, therefore, provides further reduction of worker exposure to contaminants (healthier workplace).
- More energy efficient system, as less back pressure on the fan and less shock loss results in less kW's of power needed (cost savings).



The Bad – Duct installation and blast damage

Installation issues:

- Crooked ventilation ducting.
- Damaged or torn ducting.
- Blast-damaged duct is found at any location in the system other than the last length of duct near the face.



Outcomes:

- Excessive loss of air due to shock loss or leakage. The combined leakage loss from excessive small holes on the duct is similar to the effect of one large hole.
- Ventilation ducting cannot be extended to its maximum designed distance due to excessive air losses.
- Energy inefficient system.
- Duct is hanging below pipes and has been damaged.
- Ventilation ducting is not expanded fully, meaning insufficient volume. This may be caused by a variety of factors.

Solutions:

- Straighten ducting in the back by hanging the flexible duct with a messenger cable or wire attached to eyebolts, messenger pins, rock bolts or similar approved attachments. Messenger cable used to hang the duct should be installed straight and tensioned and should not follow the contour in the back.
- Repairing holes and tears, or replacing ducting if unrepairable, is critical for getting the correct air quantity to the face. A number of small holes over hundreds of feet of duct add up to major air loss at the face (as shown by the photograph which the orange and white ducting is not fully inflated).
- Install duct opposite to piping in drift so it can be hung higher (to prevent damage).

Benefits of implementing the solutions:

- Increased airflow at the end of the ducting, therefore, provides further reduction of worker exposure to contaminants (healthier workplace).
- More energy efficient system, as less leakage and shock loss results in less kW's of power needed.

The Bad - Fans in series

Installation issues:

- Excessive gap between ducting and fan when installing fans spaced in series at intervals along the auxiliary ventilation system.
- Misaligned duct and fan in series.
- Series booster fan incorrectly positioned along duct column, resulting in collapse of duct and failure of system.

Outcomes:

- Excessive re-circulation of contaminated air.
- Increased worker exposure to contaminated air (e.g. diesel particulate matter, CO, NO2, silica dust, heat etc.).
- If an additional fan is installed in the system and the gap between duct and fan is too close, the duct may collapse.

Solutions:

- If a booster fan must be installed in series when using flexible ducting, a gap of approximately 15 cm (6 in.) between the end of the column and the booster fan should be maintained to prevent collapse of the column (due to the suction effect of the fan), and to minimize excessive recirculation of contaminated air.
- If possible, booster fans should be spaced, with appropriate blade angle settings, to avoid the requirements for a gap. This will lessen the chances for re-circulation. Use of rigid duct is required for these installations.
- Utilize rigid duct where duct collapse is an issue due to tight installation (gaps of less than a few inches). Fans may need to be turned on in a select order if rigid duct is used for a fans in series ventilation system to prevent a fan stall.

The Ugly - Duct installation

Installation issues:

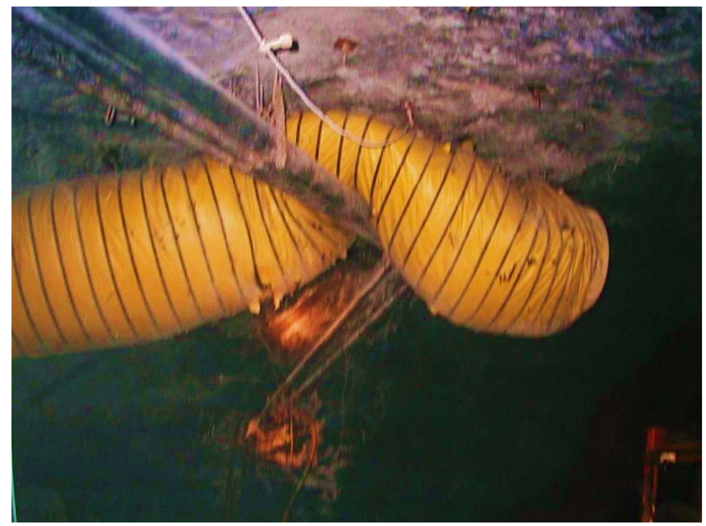
- Flexible ducting installed with excessive kinks.
- Flexible ducting not fully stretched to its full length during installation.
- Improperly installed transition piece.
- Ducting (steel, fiberglass, plastic, flexible tube) installed overtop service pipelines resulting in restricted airway.

Outcomes:

- If ducting does not minimize or eliminate obstructions (from mine services, low backs, etc.) along the duct route, it can reduce the air volume to the face by 40%.
- Excessive loss of air.
- If a flexible ducting is used on a 90-degree bend, there can be a 30% air loss from this installation. Spiral duct must be used for 90 degree bends for this reason.

Solutions:

- Straighten ducting in the back by hanging the flexible duct with a messenger cable or wire attached to eyebolts, messenger pins, rock bolts or similar attachments. Messenger cable used to hang the duct should not follow the contour in the back, it should be straight.
- Avoid installing ducting in tight locations (overtop service pipelines) to prevent restriction of the airflow inside the duct.
- When installing services in areas where ducting are already or will be installed, provide enough clearance between the services and the ducting to avoid restriction.
- If duct must be installed beyond the pipes, use appropriately sized oval piece above pipe with proper circular to oval transition piece, or pass duct below pipes.
- Ensure proper transition piece is purchased from vendor and installed.
- Ensure maintenance of ducting condition.



The Ugly – Duct of different diameter and Y's

Installation issues:

- Connecting ducting with different diameter with no appropriate adaptor.
- Connecting "Y"s with no appropriate regulator resulting in improper airflow in each split.
- Transition is not smooth.

Outcomes:

- Increased shock losses as a result of air turbulence.
- Excessive loss of air.
- Less energy efficient.
- Y`s with no proper regulator will result in improper airflow between the split.
- If there are several "Y"s or laterals to split air to multiple headings, the leakage will increase resulting in less air to the final discharge point.

Solutions:

- Proper duct adaptor and connectors should be used to connect ducting with varying diameter to avoid air turbulence and air leakage.
- Ensure maintenance of ducting condition.
- Design and maintain system to utilize the same size ducting throughout.
- Install straight as possible.
- Y installation to split air should be fitted with appropriate regulator to maintain airflow requirements for each split.
- Choke off unused areas to maximize volumes to the desired area.