Case Study - How to Effectively Lower Operating Costs through ventilation bag selection.

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ABSTRACT

During my time as operational ventilation engineer at a mining house in Australia I identified the need to better manage ventilation consumables. The need to better understand the life cycle of lay flat ventilation ducting specifically and the use there of stood out due to:

- Continues down time to production.
- Service crew availability and constraints.
- Excessive workload resulting in late delivery of ventilation construction projects.
- Long re-entry times after firing/blasting practices.
- Continues recording of poor environmental conditions by ventilation technicians.
- Poor physical condition of ventilation ducting due to vehicle damage and blasting practices.

To Better understand weather or not the operation had a valid concern I laid out a strategy to better quantify the use of ventilation lay flat ducting in the underground section through:

- Assigning the ventilation technicians with the task to conduct a full ventilation lay flat duct survey in the underground section.
- Quantifying the meter of ventilation ducting installed versus the development meters achieved for the past year.
- Establishing an operating cost for the secondary ventilation lay flat duct usage per development meter. This cost is often overlooked by management teams in the greater scale of things as it is concealed within Opex.

Reviewing the information gathered supported by the cost analysis the following actions were taken:

- Communicated to the full leadership team a strategy to:
    - Immediately impact on the conditions underground through training and education.
    - Visible felt leadership.
    - Planning of secondary ventilation installs.
- Compiled a commercial package to go to market with a tender package exclusively aimed at the supply and procurement of ventilation lay flat ducting.
- Set up a process to evaluate the cost per development meter for the installation ventilation lay flat ducting.

After the tender award and changeout of lay flat ventilation ducting at the operation had been completed I continuously compared the performance of the ducting. The evaluation process included:

- Comparing meters ventilation duct installed versus development meters mined.
- Identifying the types of ducting most consumed and analysing the:
    - Reason why.
    - Potential to improve/reduce.
- Identify where better designs may be utilised to achieve improved results.

This process formed a continues loop through the years and as will be demonstrated by results captured in the paper, delivered excellent commercial benefit to the operation. Most importantly the safety benefits through improved dilution rates resulting in better environmental conditions.

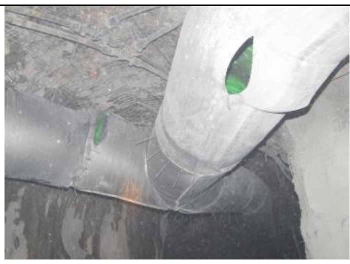
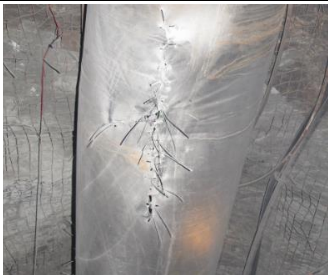
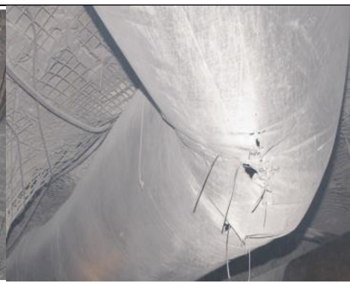
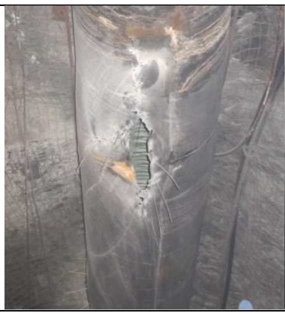
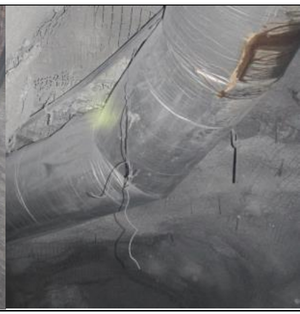
INTRODUCTION:

Ventilation systems consume a large portion of the operating budget in underground mines. This is mostly due to electrical input requirements, capital cost projects, purchasing and installation of ventilation control devices, secondary fan purchases, maintenance and manning costs. Many ventilation engineers focus on the primary ventilation circuit and fail to understand the impact of the secondary ventilation system on the operation. For a holistic approach to the health assessment of an operations ventilation system and how functionally efficient it is both primary and secondary ventilation must be considered. Unfortunately, many ventilation engineers fail to identify opportunities for improvements in the secondary ventilation system and do not understand the safety and cost associated with it. This paper will explore my findings of such a secondary ventilation system and show the results of the actions and systems put in place to benefit the operation. The focus will be on the commercial and operational benefits achieved through improving the secondary ventilation system.

ANALYSIS OF THE SECONDARY VENTILATION SYSTEM

Ventilation duct survey

To better understand and quantify concerns raised and identified in the short comings of the secondary ventilation circuit I assigned the ventilation technicians to conduct a full vent bag survey. Below is an example of some of the items captured during the survey. The survey was set up to be simple, to the point and visually easy to digest:

Location	**2 x 75kW Fan – Operating on one stage only** 1 x Straight duct 1 x Infill 1 x Branch – Replace with lobster-bak 1 Infill 3 x Straight duct	
Location	**2 x 75kW fan – Operating on one stage only** 2 x Straight duct 1 x Branch – Replace with lobster-bak 1 x Infill 2 x Straight duct 1 x Infill 1 x Straight duct	 
Location	**2 x 75kW Fan – Operating on one stage only** 4 x Straight duct – install lobster-bak onto level, fix holes in vent run just after the fan	 

As part of the survey a list of recommendations and improvements required were compiled into a report:

- Changing bag type
- Bogging floor out
- Installing bag protectors
- Installing method to be improved etc.
- Expected gain by completing recommendations.

By analyzing the information, it was possible to establish where ventilation ducting may have failed due to poor installation practices, Equipment damage or poor-quality product installed. During the first of these surveys it was identified that there are areas more prone to damage due to pressure in the bag, equipment damage or location of ventilation run. It was also clear that the product was not performing well enough for the conditions being experienced in the underground section. The areas identified where a heavier duty bag would add value and reduce daman/blow outs were within the first 70 to 100 meters after the fan. Items identified that could add value to the operation were:

- Lobster-bak on turns.
- Heavy duty branch pieces.
- Rams horn design (removal of T-Piece as a whole)
- Vent bag nappies and duct protection sheets.

Quantify Duct Use Versus Development meters

Understanding how much duct is used versus development meters mined is an easy way to assess whether your operation needs to rethink their secondary ventilation strategy. It is important to understand that it is not only ventilation bag quality that may be causing premature failure but a multitude of reasons such as:

- Wrong size bag for the fan installation.
- Buildup of the roadway causing equipment to make contact with the bag.
- Wrong profile, Profile to small causing equipment to make contact with the bag.
- Damage from protruding roof support.
- Deflated bag hanging low and being caught by equipment.

There are various ways to assess this data and it is much easier to do than many ventilation practitioners may think. At this operation I accessed the data on the SAP system but in the past, I have had to go through manual order books, work through the procurement team or contact the store man. For Development meters the production teams are a great help and will have all the information you require on hand. Once you have the information use the formula:

Total Count Vent duct purchase for year ÷ Total Development meters mined for year = Duct m/Dev m

The first year I completed the assessment at the operation 7.8meters of duct was being installed for every 1 meter of development mined.

Installation Cost/Impact on Opex

To help understand the potential cost impact it is important to find an acceptable way of costing the installation of ventilation bag in the underground section. This is extremely hard to do and to quantify. How do you show production losses due to ventilation work being carried out? I have always refrained from using production losses in the calculations as there are too many arguments to counter them with no way of quantifying it. At this operation I used the following information:

- Count of service crew personnel installing ventilation bag runs.
- Annual wage of service crew personnel per person. This may vary substantially from operation to operation.
- Equipment higher cost for an IT and LV per hour.
- Average time it takes to install a ventilation bag per meter. This takes time to be spent with the service crew and may also vary substantially depending on the size, length and weight of the ventilation bag used at the operation.

Based on this information I calculated the cost allocated from the operating budget to installing ventilation bag over the year:

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Table 1 Cost Sourcing for Cost Analysis

Workers Required		**3**
Annual Wage	**$**	**85,000.00**
Wage per min per worker	**$**	**0.68**
IT hire per hour	**$**	**52.00**
IT hire per min	**$**	**0.87**
LV hire per hour	**$**	**18.00**
LV hire per min	**$**	**0.30**
Time to strip out old bag, pick up new bag, transport to location, install, throw away old bag in min		**3**
Total cost to install 1m vent bag including all factors	**$**	**9.63**

The data reflected in Table 1 is site specific and the time must be taken to appropriately source the information for your operation to ensure the result is as accurate as possible.

Table 2 Cost Analysis

Year	Meters of vent bag purchased for the year	Development meters mined for the year	Meters installed per development meter	Time spent installing ventilation duct hours	Opex assigned to installing vent duct for the year excluding duct purchase price	% Reduction in time spent on vent by service crew Year on Year	Year on year cost saving	Comment
Before change	30732	3940	7.8	1537	$ 295,943.25	0	$ -	One service crew tied up with vent bag installs

As per table 2 it can be seen without accounting for vent duct purchasing cost and production losses that:

- 7.8 meters of vent duct was installed for every 1 meter developed.
- One service crew was tied up with ventilation work for a shift each day.
- Nearly $300K of the Opex had been allocated to ventilation duct installations.

Table 3 Compare possible benefits between product

	Supplier 1	**Supplier 2**	**Supplier 3**	**Supplier 4**
Airflow at Duct Face (m^3/s)	40.64	38.70	37.66	37.78
K – Factor	$0.00242Ns^2m^4$	$0.00337Ns^2m^4$	$0.00373Ns^2m^4$	$0.00377Ns^2m^4$
Fan Pressure (Pa)	2489	3118	3292	3328
Air Power (kW)	101.15	120.67	123.98	125.73
Assumed Fan Efficiency	75%	75%	75%	75%
Annual Running Costs @ $0.12c/kWh	$141,772	$169,131	$173,770	$176,223

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Table 3 is an analysis of 4 of the best-known bag manufacturers at that point in time and I used this table/or similar in combination with Table 2 to show a further potential cost benefit. It is important to assess products on a continuous basis to ensure your operation is benefiting from the best available technology delivering the safest most cost-effective result.

Safety

Concerns regarding environmental conditions were identified by making use of the Primary, Secondary and the vent bag survey. All points were included in a formal communication to al stakeholder, including the management team, to justify going out to market on tender. Some of the concerns identified will be relevant to most operations where secondary ventilation installations are of poor quality and/or the product is not appropriate for the installation:

- Volumes do not meet legislative requirements for the ventilation of diesel units in the area.
- Volumes delivered in the working area is insufficient to adequately dilute airborne contaminants such as heat, dust, gases, fumes, vapors and do not deliver enough flow to support thermal work limits set out in the heat management procedures.
- Long re-entry times after firings serves as a production loss but also have a safety risk for potential exposure of workers to gases and fumes. Pockets of gas may be moved through the circuit and has the potential to inundate workers.
- Larger fans installed to try and achieve the desired flow on the working face. This results in heavier lifts posing more risk to the workers conducting the task and increased power consumption (operating cost).
- Working at heights is a higher risk task and workers must spend more time handling duct at heights.
- Installation of ventilation duct in unventilated areas.
- Increased risk for man-vehicle and vehicle-vehicle interactions due to location of ventilation bag installations.

Tender process analysis and criterion

Based on the information supplied approval was obtained to prepare a tender document and to go to market. To ensure maximum value is realized during a tender process there are key outcomes to be determined before the tender is released to the market. Some of these should include:

- Internal / External stakeholder engagement to establish the desired deliverables.
- Determine the full scope of products / work to be delivered,
- Identify the key compliance criteria to be achieved that will allow the scope to be met,
- Establish a tender strategy and document pack. This will provide an unbiased full evaluation strategy and weighting of the tenderers within this document.

When preparing the tender document, it is important to understand what your site requirements are and to supply as much detail as possible to the Tenderers. When tenders are sent to market with insufficient information it may delay the tender process or as a worst case scenario procure a product that do not perform as per your expectations and to the benefit of the operation.

Table 4 Product Information list

Quantity	Size Bag mm	Bag Length meters	Strength	Description
10	1220	15	Mid	Straight bag
5	1220	3	Mid	Straight bag
5	1220	1	Mid	Straight bag
2	1220	3	Mid	90° Bent
2	1220	3	Mid	Branch piece
2	1220	3	Mid	Rams Horn
10	1400	15	Mid	Straight bag
5	1400	5	Mid	Straight bag
5	1400	1	Mid	Straight bag
2	1400	5	Mid	90° Bent
2	1400	5	Mid	Branch piece
2	1400	5	Mid	Rams Horn

Table 4 is an example of a simple list of products and counts which I included in one of my tender documents.

The tender package will determine the product, quality and services received by the company. When there is an oversupply of detail specified in a tender document, the company may exclude better technology / product. When there is insufficient detail supplied, the tender responses may not deliver to the site / companies' expectation. To ensure the tender document has a enough information, stakeholder engagement and expectation is crucial to be captured in the process. Table 5 is an example of the requirement sheet I included in the tender but this criteria must be established for each operation during the stakeholder engagement sessions and based on latest market research:

Table 5 Min Product Requirements

Material / Bag (Strength test report to be submitted with tender)		
1.1	Material Weight equal to or greater than	375 grams/m² (+/- 3%)
1.2	Weft; Wing Tear (N)	To be greater than 400N
1.3	Tensile Strength (N)	To be greater than 2000N
1.4	Warp; Wing Tear (N)	To be greater than 350N
1.5	Tensile Strength (N)	To be greater than 2000N
1.6	K factor	No greater than 0.0035 Ns^2m^4
1.7	Leakage co-efficient,	No greater than 80 mm^2/m^2
Eyelet configuration		
2.1	Size	12mm
2.2	Material	Steel (Stainless Steel preferred)
2.3	Type	Full ring lock (Spur tooth washer preferred)
Rib configuration		
3.1	# Layers of material	4 Layers if welded up to rope or 6 if sewn
3.2	Minimum distance from top of eyelet to bag opening	No greater than 50mm
3.3	Distance from top of eyelet to top of bag	No greater than 20mm
3.4	Rope type & thickness	6mm Nylon rope, ≥150kg breaking strain
3.5	Eyelet distance from end of bag	No greater than 250mm
3.6	Eyelet spacing	500mm
3.7	Clips attached?	Yes- Oval carabiner's preferred
Lo-K configuration		
4.1	# Layers of material	3 Layers if welded 4 layers if sewn

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4.2	Eyelet spacing	150mm apart
4.3	Eyelet location in relation to top of bag	Top Dead Centre
4.4	Overlap distance for Lo-K	No less than 130mm
4.5	Rope type and thickness	6mm Nylon rope, 150kg breaking strain
4.6	Eyelet distance to end of Lo-K	No more than 20mm
4.7	Clips attached?	No clips
Spigot length		
5.1	length of spigot	≤1080mm = 750mm, ≥1220mm = 1000mm
5.2	Spigot material thickness	375 grams/m² (+/- 3%)
Bag / Duct colour for different sizes		
6.1	Do we need a different colour for each bag	Yes
6.2	Will an alternating colour suffice	Adjoining bag sizes cannot be the same colour
Packaging Bags (These colours can be altered if required)		
7.1	UV Resistant	Yes - UV stabilised
7.2	Bag colour different (must clearly indicate type of bag inside)	Yes, Colour coded: 1400mm Yellow, 1220mm Blue, 1070mm Green, etc..

Testing results must be requested to ensure bag strength and durability. There are multiple testing methods which may be quoted, and proper care must be taken that the test results comply to Australian standards and that the product is manufactured to an acceptable standard (Site visits to the suppliers and manufacturers facilities add much value to the process)

Table 6 Test methods

Test Description	Test Method
Bursting Strength	AS 4878.5
Bursting Strength	AS 2001.2.19-1988
Mass	AS 2001.2.13
Tensile Strength	AS 4878.6
Tensile Strength	AS 2001.2.3.1
Tear Strength	AS 2001.2.10
Tear strength	AS 4878.7

Some other points to be captured and clarified during the tender process:

- Where is the company based?
- Where do the company distribute from and do they service your area?
- What is the turnaround time from date of order to delivery on site?
- Where does manufacturing take place?
- Who controls design and quality control processes for the product?
- Trackability of batch supply, this will allow a faulty bag to be traced back to the manufacturing process and identify the source of the problem (Will also identify other products in the batch affected).
- Safety systems, Audit systems, ISO compliance.
- Local manufacturer and/or percentage of local sourcing.

There are many more facts captured in the tender process and during the commercial offering. Taking into consideration all the tender responses we decided on a local manufacturer and supplier for the following reasons:

- In house manufacturing in Australia.
- Full control over design and manufacturing process.
- Good compliance to tender requirements.
- Second best commercial offering.
- Equal best quality/strength of product.
- Good compliance to Work Health and Safety systems.
- Established business with a long-term track record in place.
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Secondary Ventilation System Audit Post Product Change

To validate value being derived from the change annual audits were conducted over the next tow years. The audit incorporated an inspection evaluating the duct installed pre-tender over a 12 month period and post tender over a 12 month period (With a further 12 month period the following year). The findings were:

- Vent duct usage reduced from 7.8 to 4.1 to 3.7m of duct installed per meter over a two-year period
- Further reduction in Vent duct usage over the 3rd year were realised by introducing higher strength branch pieces, lobster-bak and twin duct.

Table 7 Cost Analysis

Year	Meters of vent bag purchased for the year	Development meters mined for the year	Meters installed per development meter	Time spent installing ventilation duct hours	Opex assigned to installing vent duct for the year excluding duct purchase price	% Reduction in time spent on vent by service crew Year on Year	Year on year cost saving	Comment
Before change	30732	3940	7.8	1537	$ 295,943.25	0	$ -	One service crew tied up with vent bag installs
1st Year after change	20992	5120	4.1	1050	$ 202,148.92	32	$ 93,794.33	Saving excludes Vent bag purchasing saving and does not reflect projects timeously delivered due to service crew availability (32% less time spent installing vent bag).
2nd Year after change	18426	4980	3.7	921	$ 177,438.84	12	$ 24,710.09	Saving excludes Vent bag purchasing saving and does not reflect projects timeously delivered due to service crew availability (12% less time spent installing vent bag).

Table 7 shows a cost analysis which were carried out for two years after the tender were awarded. This cost analysis added value by:

- Showing a year on year cost saving in the installation cost of ventilation bag at the operation.
- Showing a reduction in the amount of ventilation bag installed per development meter blasted (52.6% reduction in vent bag used)
- Purchase cost for ventilation bag were lower even though a heavier duty bag were used.

- Less time spent by the service crews installing ventilation bag freeing them up for other work supporting production activities.

The most value added to the operation were a significant reduction in re-entry times and improvement in environmental conditions in the working areas. With increase airflow temperatures reduced and legal compliance improved. Even though it is hard to quantify it is clear from the data that there would have been a reduction in production losses and an improvement in availability/flexibility in the production schedule.

CONCLUSION

To be a successful ventilation engineer on an operation it is important not to get lost in the management of the primary ventilation circuit and remember to pay equal attention to the secondary ventilation system. By applying a simple method of:

- Listening to my customer (Complaints from production teams)
- Analysing data (Re-Entry times, commercial data, production data)
- Investigation (Vent bag audit, secondary survey, primary survey)
- Cost Analysis
- Tender to market
- Post Tender Evaluation

Significant safety improvement, cost savings, time savings and legal compliance were achieved. At this operation the secondary ventilation system was static (no variable speed drives) and significant efficiency improvements were achieved in almost all the ventilation runs on the mine. By not just selecting the cheapest product available on the market and by installing a heavier duty more expensive bag fit for the application and the operational requirements:

- Significantly reduced the amount of vent bag installed by 52.6%.
- Had large Opex and time savings freeing up the service crew to focus on activities supporting production.
- Reduced purchasing cost for ventilation duct on a year on year basis.
- Improved safety and legal compliance.
- Reduced Re-entry times
- And most importantly reduced the amount of complaints reported to the ventilation team showing we were improving and better supporting our customer, the production team.

ACKNOWLEDGEMENTS

REFERENCES

Standards Australia. AS 4878.5 AS 2001.2.19-1988, AS 2001.2.13, AS 4878.6, AS 2001.2.3.1, AS 2001.2.10, AS 4878.7 . http://www.standards.org.au