Carbon Fibre Vent Tube Project

Xstrata Coal – Oaky North

In Brief
Analysis showed that the establishment and maintenance of our ventilation ducting was a major contributor to various injury types and their severity. Additionally, the fibreglass tubes in use were limited in their life expectancy and had structural issues that could cause them to fail in certain applications and hold up production. A project was initiated to address these issues.

The Problem
Xstrata Coal Oaky North operation applies ventilation to all underground coal faces by attaching lengths of ducting (vent tubes) to an auxiliary fan. This process creates negative pressure in the area being ventilated which draws air into the working face.

Historically, ventilation ducting was made from tin / stainless steel, later replaced by a fibreglass version which was far more durable and slightly lighter. Tubes came in various lengths, usually between 2.5 – 3.0m and could weigh in excess of 30kg each. An unfortunate feature of the tubes was that they often splintered easily when minor damage was incurred.

The task of ventilating involves lifting the vent tube above the head and securing it to the roof using a steel chain with fitted hooks. Installation occurs approximately every 30 minutes and since vent tubes are re-used during the mining cycle, there is an increased probability of injury from manual handling of splintered tubes.

Manual handling tasks include:
- Transportation to the coal face and installation into the vent tube line;
- Removing the vent tubes from the roof;
- Loading them into machine basket;
- Transportation to storage area and unloading;
- Pick up from storage area and loading into machine basket or shuttle car;

Problem for the workforce
Analysis of mechanisms of injuries in 2009 highlighted the task of manually handling vent tubes as a major contributing factor to both injury type and severity.

Problem for the business
Other issues were identified in relation to the effectiveness of the fibreglass tubes when mining sequences required longer tube lines to be installed. Longer ventilation circuits delivered increased pressures and when the pressure differential became too great for the fibreglass tubes, their shape distorted and they collapsed. This would cause production delays, ventilation issues and it limited the total distance able to be mined with a single ventilation line.

The Solution
A cross-section of the workforce, as well as physical therapists from the local community engaged in a risk assessment using the task/person/performance relationship as the context. Several models were developed to assist with the assessment process. These appear below as figure 1;2;3.

Physicality Prior to re-design

Score	Exertion	Exposure	Posture	Movement
+1	Low force and speed	Task performed infrequently for short periods	Comfortable postures within a normal range about neutral	Dynamic and varied movement patterns
+2	Moderate force or speed, but well within capability	Task performed regularly but with many breaks or changes of task	Uncomfortable postures, but not approaching an extreme range of motion	Little or no movement or repeated similar movements
+4	High force or speed but not close to maximum	Task performed frequently without many breaks or changes of task	Postures approaching or at an extreme range of motion	Repeated identical movement patterns
+8	Force or speed close to maximum	Task performed continuously for the majority of the shift		

Figure 1

Physicality After Re-design

Score	Exertion	Exposure	Posture	Movement
+1	Low force and speed	Task performed infrequently for short periods	Comfortable postures within a normal range about neutral	Dynamic and varied movement patterns
+2	Moderate force or speed, but well within capability	Task performed regularly but with many breaks or changes of task	Uncomfortable postures, but not approaching an extreme range of motion	Little or no movement or repeated similar movements
+4	High force or speed but not close to maximum	Task performed frequently without many breaks or changes of task	Postures approaching or at an extreme range of motion	Repeated identical movement patters
+8	Force or speed close to maximum	Task performed continuously for the majority of the shift		

Figure 2

Risk Ratings Pre-redesign

Consequence	Moderate	
Likelihood	D	
Risk	9	Medium

Risk Ratings post Re-design

Consequence	Minor	
Likelihood	D	
Risk	5	Low

Pre-Design – Risk Ranking of Medium
Post Design – Risk Ranking of Low

Figure 3

After assessment of the task and ergonomic considerations a project was initiated with the main objectives being:

- To reduce the weight of the tubes;
- To increase the structural integrity of the tubes to allow increased pressure;
- To reduce potential injuries due to splintering or damaged tubes

Later, after carbon fibre was selected as the development material, the following additional aim was added to the scope:

- To investigate other opportunities for the technology to transfer throughout the Oaky Creek business including longwall monorail sections and conveyor belt structure

The Chosen Solution

Carbon fibre is a reinforced material or Fibre Reinforced Polymer. It is a product that is extremely strong, very light, but is unfortunately very expensive so its use in mining applications to date has been limited. Contact was made with a New Zealand company called Rivers Carbon Fibre, a world leader in carbon fibre technology.

After discussion and mine visits from Graeme Rivers and Cary Watts of Rivers Carbon Fibre, sufficient capital was invested to manufacture a suitable ventilation tube from carbon fibre. Four prototypes were made with different blends of material and then the preferred option was tested and selected by Oaky North personnel.

Being the first to use the material for this purpose in Australian Coal there was an extensive testing and approvals process that had to be undertaken to gain approval for use underground. This included fire resistance and conductivity or electrical resistance testing.

In both of these tests the tubes passed with exceptional results as shown in the below table. Certificates are attached as Appendix 1. Testing certificates were also issued for the repair process used which also passed with exceptional results.

Picture showing autoclave unit and 4 prototype carbon fibre tubes

Summary of fire resistance test results

Requirement	Persistance to flame	Persistance to after glow
30 Seconds	0 Seconds	0 Seconds

Summary of electrical resistance test results

Requirement	Outer surface	Inner surface	Thickness	Across joint
1 million Ohms/ metre of length	12 Ohms	13 Ohms	5 Ohms	5 Ohms

Benefits of the Solution

Various benefits have been seen with the carbon fibre tubes compared to the previous fibreglass versions.

- Total weight is now approximately 9kg - just 30% of the original weight;
- The tubes have been pressure rated to over 50kpa without structural failure, (maximum auxiliary fan pressure approximately 8kpa. i.e. 6 to 1 safety factor);
- They are extremely durable and do not splinter; meaning a longer lifetime, less raw material usage in production and a lighter environmental impact
- High level of quality assurance – a tracking tag is placed on each tube for historical data collection and maintenance history;

- But of course, the largest benefit is the reduced manual handling risk through a significantly reduced effort required to install or relocate them. This is highlighted above in the Perform Matrix where the reduction in physicality was assessed as "Low".

An Oaky North team member demonstrates the lightweight nature of the new carbon fibre vent tubes

The vent tubes are now in use in all development panels with over 400 on site and the development operators are extremely impressed with the results. One mineworker on C Crew stated "In my 20 years in mining these tubes are the best improvement I have seen in development".

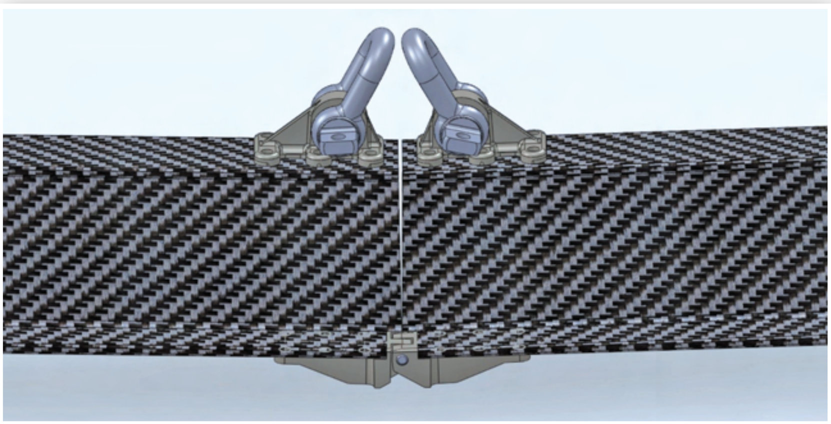
Transferability and Innovation/Originality

The transferability of this innovation is evidenced **in the endorsement provided by the director of Kinnect** - Kevin Conlon. He says that *"The installation of vent tubes in the underground environment from a continuous miner is a manual handling challenge. The high loads and awkward positions lead to an elevated risk which is clearly supported by the injury data."* *"Carbon Fibre Vent tubes are in my opinion a Game Changer that in the future will simply become industry best practice."*

The applicability of carbon fibre vent tubes however, is not limited to underground coal mines. They have application for all mines and industry where ventilation systems incorporating the use of vent tubes exist. The success of the strong, lightweight ventilation tubes, the obvious safety benefits and the acceptance by the workforce has convinced Oaky North Colliery to make a significant investment in investigating the possible use of this material in other areas of the mine.

In accordance with the Oaky Creek risk management process, the present focus is on the longwall mining process where the most regularly manhandled heavy equipment sections are mono rail beams (see drawing) and conveyor structure. The aim of these projects is to reduce the exposure of the mineworkers to the risk of injury by reducing the physical weight of these components without reducing structural integrity and longevity of the component.

Across the mining industry there are many other heavy components that are currently made of steel or hardened neoprene that could be made from carbon fibre. These options will also be investigated as time allows in an effort to continually improve the health and safety of the workforce.



Drawing of longwall monorail, this unit is 10 kg against original steel beam and joiner weight of 36kg

Appendix 1 – Testing Documentation

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Graeme Rivers
Rivers Carbon Technologies
P.O. Box 24670, Royal Oak
AUCKLAND 1345 NEW ZEALAND

26/10/10

TEST REPORT 10/1147

Company:	Rivers Carbon Technologies
Sample Description:	RM600 – black carbon fibre ventilation pipe
Intended Use:	Non-metallic rigid ventilation ducting
Sample No.:	10/1147

SUMMARY

The material **complied** with the fire property requirements of *MDG3006 MTR8, Section 4.4a)*.

The material **complied** with the electrical property requirements of *MDG3006 MTR8, Section 4.4a)*. The internal surface resistivity of joined duct pieces fitted with coupling band **complied** with the electrical resistance requirements of *MDG3006 MTR8, Section 4.3c)*.

The oxygen index of the material was determined according to the requirements of *MDG3006 MTR8, Section 4.4b)*.

Analysed by: Checked by: J. Sanders

Yours faithfully,

G. Slater
Manager
Mine Safety Technology Centre

Fire Resistance

Sample:
RM600 – black carbon fibre ventilation pipe

Results:

Test No.	Persistence of Flame (sec)	Persistence of After Glow (sec)	Extent of Charring (mm)
1	0	0	120
2	0	0	105
3	0	0	110
4	0	0	115
5	0	0	120
6	0	0	120
Mean	**0 sec**	**0 sec**	**115 mm**

Notes:
a) The test results relate only to the behaviour of the test pieces under the particular conditions of the test; they shall not be used as a means of assessing the potential fire hazard of the product in use.
b) Sample sizes: 300 mm x 300 mm curved duct sections.
c) Laboratory ambient conditions: 25°C, 52% relative humidity.

Method of Analysis:
AS 1180.10B 1982 *Determination of combustion propagation characteristics of a horizontally oriented specimen of hose using surface ignition.*

Any variation from Standard/Test Method: Yes-
- AS 1180.10B:1982: The Analite No. T203 burner replaced with a Bunsen type burner in accordance with the annex to ISO340.
- Due to large diameter of duct, samples cut as described for testing.

Requirements:
The average persistence time for flaming and glowing shall not exceed 30 seconds.

Sample Status
The material **complied** with the fire property requirements of *MDG3006 MTR8, Section 4.4a)*.

Industry & Investment NSW - MINE SAFETY TECHNOLOGY CENTRE
PO Box 343 Hunter Region Mail Centre NSW 2310
8 Hartley Drive, Thornton NSW 2322
Tel: 61 2 4924 4000; Fax: 61 2 4924 4080
www.industry.nsw.gov.au
ABN 72 189 919 072

Electrical Resistance - Single duct sections

Sample:
RM600 – black carbon fibre ventilation pipe
Approx. 600 mm ID, 610 mm OD non-metallic rigid duct

Results:

Test Piece Number	Electrical Resistance ($\Omega.m^{-1}$)		
	Outer Surface	Inner Surface	Through Resistivity
1	11*	13*	3*
2	21*	11*	8*
3	3*	14*	3*
Mean	**12 $\Omega.m^{-1}$**	**13 $\Omega.m^{-1}$**	**5 $\Omega.m^{-1}$**

Notes:
a) Electrical contact between ring electrodes and inner or outer surface of duct as required.
b) 'Outer surface' measurements – electrodes at each end of duct, both contacting outer surface
'Inner surface' measurements - electrodes at each end of duct, both contacting inner surface.
'Through resistivity' – electrodes at each end of duct; one contacting the duct inner surface, one contacting the outer surface of duct.
c) Test specimens placed on insulating polyethylene plate block during testing.
d) Mean laboratory ambient conditions during testing: # 1 - 23°C, 50% relative humidity.
2 & # 3 - 22°C, 60% relative humidity.
e) Sample lengths: # 1 – 1470 mm; # 2 & # 3 – 995 mm.

Method of Analysis:
AS 1180.13A-1983: Determination of Electrical Resistance of hose and hose components

Any variation from Standard/Test Method:
- * Resistance value measured on 400kΩ resistance range on megohmmeter.
- Samples tested as received.

Requirements:
When the material is tested accordance with *AS 1180.13A – 1983*, using flexible ring electrodes connected to the external and internal surfaces, the electrical resistance shall not be greater than 1 Megohm per metre length (1 $M\Omega.m^{-1}$).

Sample Status:
The material **complied** with the electrical property requirements of *MDG3006 MTR8, Section 4.4a).*

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Electrical Resistance - Joined duct sections

Sample:
RM600 – black carbon fibre ventilation pipes (Approx. 600 mm ID non-metallic rigid duct)
300 mm wide black joining bands

Results:

TABLE 3

Joined Test Pieces	Inner Surface Electrical Resistance ($\Omega.m^{-1}$)
(A) & (B) + joining band	5*
(A) & (C) + joining band	3*
(B) & (C) + joining band	7*
Mean	**5 $\Omega.m^{-1}$**

Notes:
a) Electrical contact between ring electrodes and inner surfaces of joined ducts. Electrodes positioned at 'far' ends of joined duct sections.
b) Test specimens placed on insulating polyethylene plate block during testing.
c) Mean laboratory ambient conditions during testing: 22°C, 60% relative humidity.
d) Electrode spacing: A & B and A & C – 810 mm; B & C – 670 mm.
e) Joined duct sections tested with coupling band fitted across shouldered duct join. The bands were supplied directly from Xtrata Oaky North mine, and not from the duct manufacturer. (The bands are currently used with the existing ventilation ducting at the Oaky North site.)

Method of Analysis:
AS 1180.13A-1983: Determination of Electrical Resistance of hose and hose components

Any variation from Standard/Test Method:
* Resistance value measured on 400kΩ resistance range on megohmmeter.

Requirements:
When the joined duct material is tested accordance with *AS 1180.13A – 1983*, using flexible ring electrodes connected to the internal duct surfaces, the internal surface resistivity shall not be greater than 1 Megohm per metre length (1 $M\Omega.m^{-1}$).

Sample Status:
The electrical resistance readings obtained from the inner surfaces of joined duct sections (with non-metallic joining band) **complied** with the requirements of *MDG3006 MTR8, Section 4.3c).*

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Oxygen Index

Sample:

RM600 – black carbon fibre ventilation pipe

Results:

	% O_2 to sustain 180s burning after ignition
Oxygen Index	44.0

Notes:

a) Oxygen concentrations are percentage by volume.
b) Top surface ignition.
c) Sample sizes used were 6 mm x 20 mm x 150 mm.
d) Samples were conditioned at 23°C, 50% relative humidity for >88-hours prior to testing.
e) The result relate only to the behaviour of the test specimens under the conditions of the test and these results shall not be used to infer the fire hazards of the materials in other forms or under other fire conditions.

Method of Analysis:

ISO 4589-2:1996(E) Determination of Burning Behaviour by Oxygen Index – Part 2 Ambient-temperature test.

Any variation from Standard/Test Method:

Sample sizes as stated.

Sample Status:

The Oxygen Index of the material was determined according to the requirements of *MDG3006 MTR8, Section 4.4b).*