# SCRUBBER SYSTEM
# CASE STUDY

## *Air Quality Working Group Information Package - Part 6 of 12*

**December 2018**

# Scrubber System Case Study

This document was produced to provide information on control measures that can be used to reduce exposure to dusts and silica during tunnel construction. It has been developed by volunteers of the ATS Air Quality Working Group drawing on the collective experience of those working across some of Australia's largest tunnelling projects.

The Air Quality Working Group (AQWG) was formed in 2017 as a collaborative platform to enable industry to work together to develop and implement health strategies in conjunction with regulatory efforts to improve occupational health outcomes, with an initial focus on respirable crystalline silica ("silica dust").

The AQWG membership collectively produced reference material for purposes of communicating information that currently does not exist in the tunnel construction industry's body of knowledge. There are 12 parts to the information package, and each part must be considered in the context of the other. This document represents Part 6 of 12 total parts as listed in **Table 1**. Documented material is considered to benefit the wider tunnelling industry and therefore is freely available on the ATS website.

**Table 1 – Complete list of material produced by the AQWG**

| Part | Document Title | Document Reference |
|---|---|---|
| Part 1 | NSW Air Quality Working Group Background & Methodology – Silica Dust Exposure and the Tunnelling Industry | Doc No. AQWG_0_0.07 |
| Part 2 | Good Practice to Control Silica Dust Exposure During NSW Tunnel Construction | Doc No. AQWG_1_0.08 |
| Part 3 | Silica Dust Awareness Package | Doc No. AQWG_2_0.21 |
| Part 4 | Silica Dust Awareness Package Speakers Notes | Doc No. AQWG_2a_0.04 |
| Part 5 | Design and Procurement - Industry Considerations | Doc No. AQWG_3_0.09 |
| Part 6 | Scrubber System - Case Study | Doc No. AQWG_4_0.09 |
| Part 7 | Ventilation During Tunnel Construction - Industry Considerations | Doc No. AQWG_5_0.08 |
| Part 8 | Portal Misting System - Case Study | Doc No. AQWG_6_0.05 |
| Part 9 | Roadheader Cabin Air Filtration - Case Study | Doc No. AQWG_7_0.06 |
| Part 10 | Respiratory Protective Equipment - Industry Considerations | Doc No. AQWG_8_0.07 |
| Part 11 | Monitoring RCS Exposure - Industry Considerations | Doc No. AQWG_9_0.07 |
| Part 12 | Health Monitoring for NSW Tunnel Construction Workers – Industry Considerations | Doc No. AQWG_10_0.14 |

This case study provides information on a scrubber system quick reference document that was used on a mined tunnel project to inform persons responsible for relocating scrubber systems on their setup, limitations, and information for their relocation during excavation. Such information may be useful for projects considering providing such information to operations personnel.

## Scrubber System Setup

Ventilation at each face development is provided through axial fans located at the surface or close to the portal. These fans provide fresh air to the mainline tunnels using forced ventilation. The air to the face (in ventilation tunnels) is provided by using scrubber fans in a forced overlap system. A simple representation of the forced overlap system is shown in **Figure 1**.

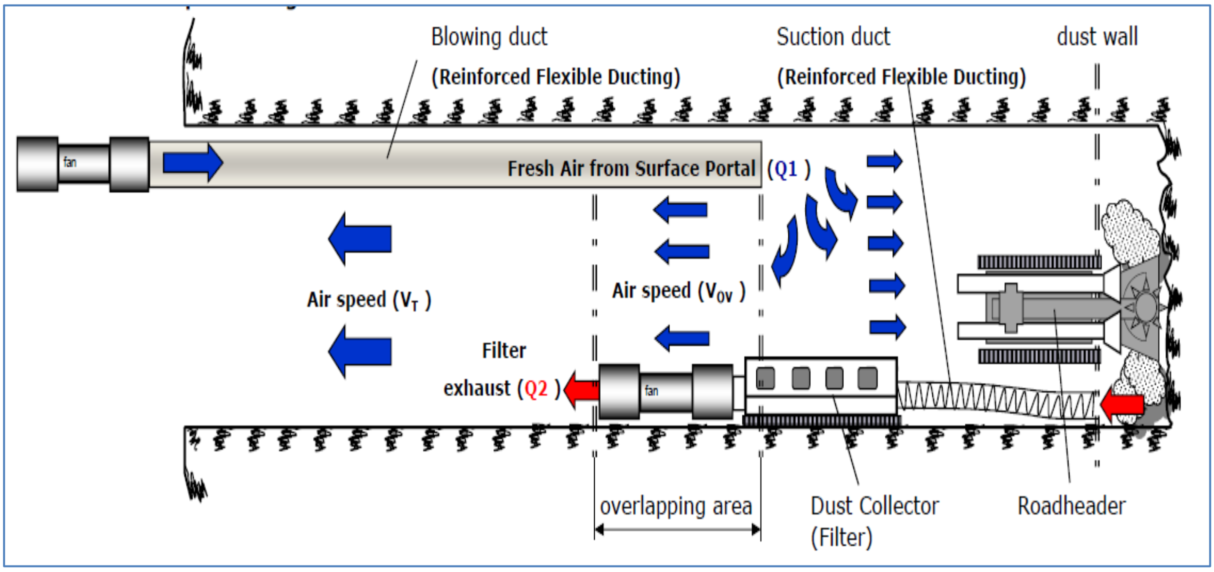


**Figure 1: Forced overlap ventilation system (credit: BBE Consulting)**

The following points may help non-ventilation engineers understand the requirements to set up a scrubber fan system:

- The selection of a scrubber for extraction face ventilation is normally based on the size of the tunnel to be ventilated. The minimum quantity required to ventilate the tunnel face will depend on the minimum velocity requirement. (This is assuming a forced overlap system where the area ventilated by the scrubber normally has more electric, rather than diesel-powered machines. Typically, 0.3 m/s[1] is used in a face ventilation system calculation for an area ventilated by a scrubber fan (extraction ventilation). The quantity of air required is calculated from the following formula

$$Q\ m3/sec = A\ (m2) x\ V\ (m/s)$$

As an example, if the tunnel heading size is 85 m$^2$, then the minimum quantity of air required could be calculated as follows:

$$Q\ m3/\sec = 85\ m2\ x\ 0.3\ m/s$$

$$Q\ m3/\sec = 25.5\ m3/sec$$

This is the minimum size of the scrubber required to ventilate the area.

[1] *Face Ventilation velocity helps in preventing the roll-back of dust into workings behind the face. Generally, the higher the velocity of air moving towards the scrubber, the better. However, when the size of the tunnel goes above 100 m$^2$, maintaining a velocity of 0.5 m/s becomes difficult due to the size of the scrubber required to achieve this velocity. Therefore, in this example, the velocity of 0.3 m/s was utilised. Alternative methods can be employed by using a lead/trail cutting sequence along with a fully enclosed road header cabin, to extract the dust effectively. Roll-back can also occur if the fresh air bags are too close to the face.*

- The total quantity of air provided by the fresh air vent bag must be higher than the scrubber capacity. For example, in Figure 1: Q1 > Q2 if a 40 $m^3$/sec scrubber is used, a quantity of at least 41 $m^3$/sec should be supplied via the vent bag to ensure that there is no recirculation of air by the scrubber fans[2].

- The exhaust of the scrubber should be positioned between 0 m to 10 m out-bye from the outlet of the fresh air vent bag to maintain the overlap[3].

- A scrubber should not operate below its stall point. For example, a 40 $m^3$/sec scrubber with 2 x 110 KW fans fitted with a CFT scrubber system should not operate below 32 $m^3$/sec capacity. If the air pulled through a scrubber is less than the quantity at its stall point, the scrubber should be checked for blockage or excessive ducting.

- The scrubber inlet should be kept as close as possible to the cutting face, with the inlet preferably located no more than 10 m behind the roadheader cutting head. The scrubber inlet can be placed in front of the roadheader cutting head, depending on the cutting sequence[4].

- As a rule of thumb, the scrubber fan suction inlets should be at least 40 m to 50 m away from the outlet of the fresh air vent bag if no diffuser is used. If a diffuser setup is used at the outlet of fresh air vent bag, this distance can be reduced.

- This is because the air that comes out of the vent bag has a velocity pressure which will form a turbulent zone as shown in **Figure 2**. This Turbulent zone changes depends on the size of the vent bags, quantity of air delivered by the bags, and the cross section of the tunnel.

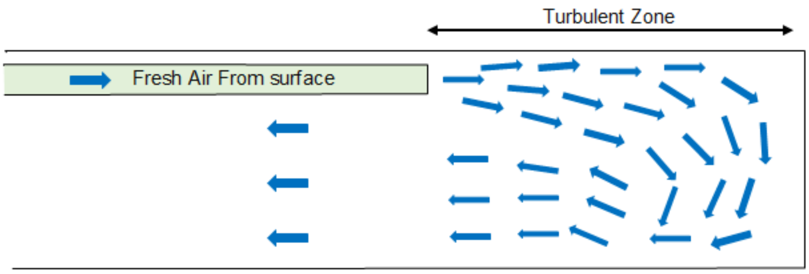


**Figure 2: Typical Turbulent Zone from the outlet of Fresh Air**

[2] *This is only applicable when there is no risk in building up of toxic gases. In case of toxic gases build up risk, the fresh air quantity should be at least 30% more than scrubber capacity.*

[3] *The minimum distance can be zero because when air comes out of the fan, it travels a distance due to velocity pressure, which effectively forms an overlap. A maximum distance is required, because if the overlap is too far, there will be a dead zone.*

[4] *Which will depend on how far the cans/ducts can be advanced under the supported roof. Typically a cut may include a 5m advance for example. This also assumes that the roadheader cabin is enclosed and filtered under positive pressure, and that the area from the rear of the road header body is restricted only to personnel utilising high-grade respiratory protection (e.g. P3 RPE). Advancing cans with a maximum of 10m from face is acceptable. The cut rate is normally dictated by ground type rather than by ventilation.*

- If a reducer or an expander section is used in the ducting, it must be made for purpose and have a sloping angle less than $10^0$ as per **Figure 3.**

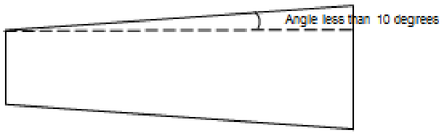


**Figure 3: Expander section**

- **Table 2** was produced as a quick reference tool to better understand how far a scrubber system can be installed from the cutting face dependant on the system configuration. It was produced for non-ventilation engineers as a simplified approach to determining pressure losses. **Table 2** is specific to the scrubber system utilised on the project (CFT) and should not be replicated for other systems without input from a Ventilation Engineer with due regard to the design of the tunnel ventilation system. It is presented here as a good example of how such calculations can be simplified for operations personnel.

**Table 2: Quick reference tool to pressure losses for 35m3/sec and 40m3/sec scrubber systems**[5]

| Components | 2 x 110 KW fan with 40m$^3$/sec scrubber | | 2 x 90 KW fan with 35m$^3$/sec scrubber | |
|---|---|---|---|---|
| | PRESSURE DROP<br>For 40 m$^3$/sec flow | PRESSURE DROP<br>For 35 m$^3$/sec flow | PRESSURE DROP<br>For 35 m$^3$/sec flow | PRESSURE DROP<br>For 30 m$^3$/sec flow |
| 1 Section of Expander from 1.4 m to 1.6 m | 32 Pa | 25 Pa | 62 Pa | 18 Pa |
| 1 Section of Expander from 1.2 m to 1.4 m | 60 Pa | 46 Pa | 46 Pa | 34 Pa |
| 90 degree bend in a 1.4 m duct (rounded end) | 150 Pa | 92 Pa | 92 Pa | |
| Slider connection from 1.2 m to 1.4 m duct | 112 Pa | 86 Pa | 86 Pa | 63 |
| Slider connection from 0.9 m to 1.2 m duct | 356 Pa | 272 Pa | 272 Pa | 200 Pa |
| Slider connection from 720 mm to 1.2m duct | *Not used* | | | 490 Pa |
| 1 m of 720 mm spiral duct | | | | 358 Pa |
| 1m of 900 mm spiral duct | 188 Pa | 144 Pa | 144 Pa | 105 Pa |
| 1m of 1.2 m spiral duct | 39 Pa | 30 Pa | 30 Pa | 22 Pa |
| 1m of 1.4 m spiral duct | 17 Pa | 13 Pa | 13 Pa | 10 Pa |
| 1m of 1.6 m spiral duct | 8 Pa | 6 Pa | 6 Pa | 5 Pa |
| **MAXIMUM ALLOWABLE PRESSURE DROP IN EACH CONFIGUARATION** | 1000 Pa | 2000 Pa | 1000 Pa | 2000 Pa |

[5] *The minimum size of ducting used in the 40 m3/sec scrubber system was 900 mm in diameter. The ducts or bags could be positioned on either side of the scrubber as long as the total distance was under the maximum distance limit. The values in the table were based on obtaining maximum flow from the scrubber system. Additional sections of ducting could be used it was allowable to drop the airflow, dependant on the fan curves.*

- To find the maximum distance a scrubber can be setup without moving, the formula below is used.

$$\textbf{Distance scrubber can be used without a move}(\boldsymbol{m}) = \frac{\text{Allowable pressure loss} - \text{Summation of all Pressure loss due to Expanders, sliders and bends (Pa)}}{\textit{Pressure loss due to a metre section of spiral duct used}(Pa)}$$

The "allowable pressure loss" is based on a 35 $m^3$/s and a 40 $m^3$/s scrubber configuration which was used on the Project. It is noted that the pressure loss will vary where different scrubber fan configurations are utilised.

As an example, if the system configuration consists of the following listed components, and using the pressure loss equivalent listed in Table 1, then the maximum distance a scrubber can be used from the excavation face without relocating it Is calculated as per the formula overleaf.

- 1 x Expander from 1.6 to 1.4m (32 Pa)
- 1 x 90 degree bend in 1.4 m section (150 Pa)
- 1 x slider from 1.4 to 1.2 m (112 Pa)
- 3 m of 1.2 m spiral duct (3 x 39 Pa)
- The rest of the system components comprise of 1.6 m spiral ducting (8 Pa)

$$\textbf{Distance scrubber can be used without a move }(\boldsymbol{m}) = \frac{\text{Allowable pressure loss (1000)} - (32 + 150 + 112 + (39 \text{ x } 3)}{8(Pa)}$$

$$\textbf{Distance scrubber can be used without a move}(\boldsymbol{m}) = 74 \textit{ metres}$$

The configuration that would be considered acceptable to achieve 35 $m^3$/s in a 2 x 110 kW scrubber fan configuration is shown in Table 3.

**Table 3: Example configuration to achieve 35 m3/s in a 2 x 110 kW scrubber system**

| Ducting Size | Equivalent Pressure Drop (Pa) | Total Length (m) | Total Pressure Drop |
|---|---|---|---|
| 1 m of 1.2 m spiral duct | 30 | 20 | 20 x 30 = 600 |
| Slider connection from 1.2 m to 1.4 m duct | 86 | N/A | 86 |
| 1m of 1.4 m spiral duct | 13 | 80 | 13 x 80 = 1,040 |
| 1 Section of Expander from 1.4 m to 1.6 m | 25 | N/A | 25 |
| **Total Pressure Loss Calculation =** | | | 600 + 86 + 1,040+25 = **1751** |

As the calculated total pressure drop is less than 2,000 Pa, the above configuration would be considered appropriate to achieve 35 $m^3$/sec of airflow.

## References and Further Information

Subsurface Ventilation and Environmental Engineering, Malcolm McPherson 1993

## Disclaimer

This document has been developed by volunteers of the ATS Air Quality Working Group and draws on the collective experience of those working across some of Australia's largest tunnelling projects. The publication comprises 12 parts, and each part should be considered in the context of the other parts. The information contained in this document is for general information and educational purposes only; it is not a comprehensive list of all factors to be considered and is not a substitute for legal or technical advice. Accordingly, you should consult with appropriate professionals and make your own inquiries as to the suitability of the information for your specific purposes.

This document should not be reproduced in whole or in part, in any manner or form, without the prior written permission of the ATS. While examples of ventilation and scrubber sizes are provided, it is noted that the ATS does not make recommendations on specific ventilation systems. Material is provided for information only and Contractors would be expected to make independent enquiries as to the suitability of such for their own use.

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