

# **APPENDIX A2**

**ALSTOM POWER  
AIR CLEANING SYSTEMS FOR ROAD TUNNELS**





## **NO<sub>2</sub> GAS CLEANING SYSTEM**

### **INTRODUCTION**

In 1992 ALSTOM Power AS, at the time ABB Miljø AS, started to investigate the possibility of developing a system that remove hazardous component NO<sub>2</sub> from the air in road tunnels and parking houses. This process was initiated by the Norwegian Public Roads Administration. The gas cleaning process was developed in co-operation between ALSTOM Power AS and the Norwegian Public Roads Administration. The technology has been commercially available since 1998.

### **TECHNICAL**

#### **Process**

The process is based on catalytic reactions, which decomposes the undesirable gases into non-toxic elements N<sub>2</sub>, NO, and CO<sub>2</sub>. The gas cleaning plant is basically a bed filled with catalyst. The polluted air is passed through the catalytic bed where the reactions take place, and the undesirable gases are decomposed. Fans discharge the cleaned air back into the tunnel or out to the environment. However CO and NO gas are not removed, but these components are not present in concentrations that would be hazardous to the human health. Particulate impurities are removed by the use of electrostatic precipitator upstream the gas cleaning plant.

#### **System Components and Utilities**

It is mandatory to install an electrostatic precipitator upstream the NO<sub>2</sub> gas cleaning plant, to prevent the catalyst from being coated with dust.

Typical system components for a NO<sub>2</sub> gas cleaning plant are bed filled with catalyst. The bed is elevated above the ground, and the polluted air is transported in ducts under the bed. The polluted air is introduced in one end of the duct, distributed and passed through the entire catalyst cross section. Dampers installed at the opposite end of the duct, make it possible to bypass the gas cleaning plant if necessary. The dampers are installed with actuators. Fan(s) downstream the gas cleaning plant exhausts the clean air back to the tunnel or out to the environment. Measuring equipment for NO<sub>2</sub> are installed upstream and downstream the gas cleaning plant to properly monitor the efficiency of the system. Fan(s), dampers and measuring equipment are controlled by a PLC. Dedusting of the catalyst is handled by special equipment isolating sections of the catalyst, dedusting it with air and injecting the polluted air upstream the electrostatic precipitator.

No hazardous materials are used in the NO<sub>2</sub> gas cleaning system, and the system requires only air and electricity to operate.

#### **Pilot plant**

The process has been tested more than 24.000 hours with actual road tunnel air in an industrial scale pilot plant located in the heavily trafficked "Festnings" tunnel in downtown Oslo. During the test period, several types of catalyst were tested to ensure maximum efficiency, 85 – 90 % for NO<sub>2</sub>. The selected catalyst has shown no loss of catalytic cleaning effect, but dedusting of the catalyst was required after 16.000 hours due to pressure loss. No other special maintenance was necessary.

# ALSTOM

## The ALSTOM Power Catalyst and System performance

The gas cleaning system removes  $\text{NO}_2$ , but not  $\text{NO}$  from the polluted ventilating air.  $\text{NO}_2$  is the hazardous component, but  $\text{NO}$  will oxidise to  $\text{NO}_2$  in the presence of oxidisers such as  $\text{O}_3$ . In longer road tunnels, there is no  $\text{O}_3$  present, however it is controversial that it is sufficient to remove only  $\text{NO}_2$  in city tunnels.

$\text{NO}_2$  are present at 7 to 10 % (by volume) of the  $\text{NO}_x$  concentration. Depending on tunnel conditions,  $\text{NO}_2$  concentration may range between 200 to 1000 ppbs and  $\text{NO}$  concentration 3 to 10 ppm in the exhaust air. Air cleaned by the ALSTOM Power catalytic process will contain typically 40 ppb of  $\text{NO}_2$ , no traces of  $\text{O}_3$ , but contain the 3 to 10 ppm of  $\text{NO}$ . Outside the tunnel this air mixes with ambient air which in a city may contain typically 60 ppb of  $\text{NO}_2$ , 80 ppb of  $\text{NO}$ , and 20 to 30 ppb of oxidants (mainly  $\text{O}_3$ ).

In the mixing zone outside the tunnel,  $\text{NO}_2$  concentration is the result of mixing ratios of the two air qualities, with the addition of a slight reaction between  $\text{NO}$  and  $\text{O}_3$  to form  $\text{NO}_2$ , due to the increased  $\text{NO}$  concentration. The limiting factor for new  $\text{NO}_2$  formation is related to the  $\text{O}_3$  content in ambient air. The added  $\text{NO}_2$  in the mixed air will be less than the 20 to 30 ppb of  $\text{O}_3$  in ambient air, at any mixing ratio.

The formation of  $\text{O}_3$  in ambient air is a complex and slow photochemical process. Any influence of newly formed  $\text{O}_3$  in the air during the short retention time in the mixing zone may be neglected.

From the above one can calculate that cleaned or polluted tunnel air will give different  $\text{NO}_2$  concentrations in the near mixing zone around the tunnel outlet. The gas cleaning system reduces  $\text{NO}_2$ . For the  $\text{NO}_2$  concentrations in the near mixing zone it makes little difference if  $\text{NO}$  is cleaned out of the tunnel air. For the city atmosphere, there is normally not much difference if a city tunnel exhaust air is cleaned or not. The difference will be in the vicinity of the tunnel portal or tunnel exhaust stack.

## Applicability

The gas cleaning system has primarily two different applications for tunnels, in longer tunnels or shorter city tunnels. In longer tunnels, pollution problems are generally related to the air quality within the tunnel, and the gas cleaning system cleans and re-uses the ventilation air within the tunnel. In city tunnels, pollution problems are primarily related to the city air quality and more specifically to the contents of dust,  $\text{NO}_2$  and VOC. The air cleaning technology is advantageous for cleaning the polluted ventilation air from the tunnel before discharging it into the urban environment. Using the gas cleaning system may reduce ventilation air volume, saving energy and money. The fact that cleaned tunnel air may contain relatively high concentrations of  $\text{NO}$  and  $\text{CO}$  is not critical in this context. These gases have no toxic or air polluting effects in the concentrations for this application.  $\text{CO}$  is quickly diluted, and  $\text{NO}$  will only react further to  $\text{NO}_2$  in contact with ozone, which is not or only insignificantly present in slightly polluted city air. The gas cleaning system can also be applied to parking houses to improve in-house air quality.

# ALSTOM

## REFERENCE PLANT

### The Laerdal tunnel

The first commercial NO<sub>2</sub> gas cleaning system was purchased by the Norwegian Public Roads Administration. The Norwegian Public Roads Administration is building a tunnel between Aurland and Laerdal, the longest road tunnel in the world. The total length is 24,5 km. The tunnel is longitudinally ventilated. There is one ventilation air exhaust shaft, 18 km from the Aurland end of the tunnel. About 10 km from Aurland, a cleaning plant for the tunnel ventilation air is installed in a short side tunnel. This plant cleans the passing air for critical polluting components, thus maintaining an acceptable air quality throughout the tunnel even during periods of heavy traffic, thus limiting the air volume and jet fan power consumption which is required to ventilate the long tunnel satisfactory.

The air cleaning plant consists of an electrostatic precipitator to remove particulate impurities, followed by ALSTOM Power's gas cleaning plant that removes critical polluting gaseous components from the air.

The upstream electrostatic precipitator is proven technology especially developed for tunnel air cleaning purposes by the Norwegian company CTA, and is highly efficient. It will remove 90-95% of the respiratory particles (PM<sub>10</sub>) in the air.

The downstream gas cleaning system removes 85-90 % of the NO<sub>2</sub> gas. The VOC gases (Volatile Organic Carbon – un-combusted gasoline and diesel gases) are also removed but to a variable extent. Peak values of VOC may be reduced by 60 %, and 75 % or more for Benzene and similar aromatic and polyaromatic hydrocarbons. Ozone (O<sub>3</sub>) is removed to 100%.

The air quality in the tunnel will be continuously monitored, and the air cleaning system will go automatically into operation when required for air quality reasons. The electrostatic precipitator will be automatically quenched for dedusting at regular intervals, while maintenance (dedusting) of the gas filtration catalyst is expected to be required at intervals of several years.

For the Aurland/Laerdal tunnel the exhaust of spent and polluted air through the ventilation shaft is not a problem. The shaft exhausts in a non-populated area.



**APPENDIX A3**  
**CLEAN TEQ PTY LTD**





## ADVANCED BIOLOGICAL OXIDATION APPLICATIONS -

Advanced Biological Oxidation uses specific bacteria and / or fungi immobilised onto proprietary filter media. The technology is supplied in two forms

- OdorTeq™ BTF
- BioFilters

Both OdorTeQ™ BTF and BioFilters will provide highly effective removal of odours, toxics and volatile organic compounds (VOCs), including:

- Hydrogen Sulphide
- Ammonia
- Methyl Mercaptan
- Ethanol
- Methyl Ethyl Ketone
- Acetone
- BETX
- Styrene
- Acrylate

Clean TeQ has developed computer modelling programs for the sizing of BioFiltration and OdorTeQ™ BTF systems. The models include a database of more than 40 different contaminants.

By construction of specifically designed housings, careful selection of media, assessment of operating conditions and use of control feedback, it is possible to optimise the capacity of the system and minimise the size of the system.

Clean TeQ's proprietary media types are known by the brands

- BioFiltaire for BioFilters
- CleanPaQ™ for OdorTeQ™ BTF

OdorTeQ™ BTF can also be retrofitted to existing Chemical Scrubbers to provide significant cost-savings with similar performance (through the use of CleanPaQ™) and with virtually no ongoing costs. Retrofit of OdorTeQ™ BTF will usually pay for itself within a 12-month period.

Clean TeQ designs and manufactures biological systems operating at airflows from 100 cu m/h to 1,000,000 cu m/h. The removal efficiencies for Advanced Biological Oxidation systems can be designed to meet the most stringent compliance requirements.

Food	Chemical compounding
Pet food	Petrochemical
Rendering	Printing
Feed milling	Fibreglass manufacture
Sewage Treatment	

## FLUID BED SCRUBBER APPLICATIONS

Clean TeQ FluidTeQ™ is a fluidised bed scrubbing technology designed to provide high efficiency and dual action. Traditionally, when gas and particulate were present in a gas stream, a two-process scheme was used, e.g. Venturi or bag house plus fixed bed scrubbers. FluidTeQ™ combines the two processes into a single package with savings in energy, capital cost and footprint.

### Technology

The proprietary ellipsoidal packing is fluidised within the scrubber. The ascending gas and descending liquid flows are contacted counter currently within the FluidTeQ™ fluidised bed and produce a highly turbulent mix. The rapid multiphase shearing forces generated by the turbulence leads to intimate multiple contacts. The benefit of this rapid mixing is a greatly enhanced interfacial area and mass transfer coefficients. The additional effect of rapid particle wetting with intense impacting is perfect for high removal of very fine particles.

### Upgrade Fixed Bed Scrubbers

Many existing gas scrubbing systems employ fixed packing as the contacting medium between contaminated gas and liquid. These systems are limited in their range of operations due to the limited range of viable mass transfer and pressure drop. FluidTeQ™ operates with a fluidised bed and is less prone to flooding providing a much greater operating range. Existing packed bed scrubbers can be easily upgraded to a fluid bed system, providing increased efficiency or increased treated air volume.

### Materials of Construction

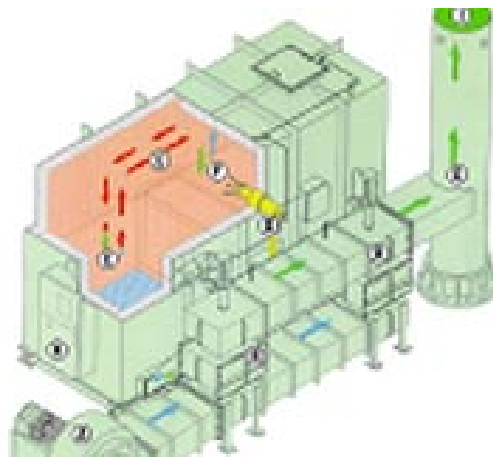
The FluidTeQ™ is constructed from corrosion resistant Vinyl Ester Resin Fibreglass, 316 S.S. PVC, and ABS. The Ellipsoid Packing is chemical, heat and mechanical wear resistant.



- Oil Refineries
- Chemical Plants
- Biosolids Handling
- Fertiliser Production
- Smelters
- Galvanising Plants
- Sewerage and Wastewater

## REGENERATIVE THERMAL OXIDATION

Regenerative Thermal Oxidation is designed for applications where combustible volatile organics or odours are present in the gas stream. Clean TeQ partners with Adwest, USA for the design, manufacture and installation of the RETOX® range of RTO's for our region. The RETOX® unit consists of two ceramic catalyst beds. An independent gas train with a burner is used for pre-heating the bed or to inject gas into the process gas stream to maintain the temperature within the combustion beds.



### RETOX® RTO FEATURES

RETOX® twin bed RTO modules skid mounted, shop assembled

Engineered twin ceramic media beds with minimal pressure drop through unit

Standard sizes from 1,000-100,000 cu. m per h with 95% heat exchanger thermal efficiency and leak proof forced draft design

Fuel free operations at >3% LEL

Natural gas injection after start-up

Proven Airex poppet valve flow control

Fully wired, pre-tested automatic controls

TEL-MAX Telemetry remote diagnostics

High density internal compressed ceramic fibre insulation

### RETOX® RTO BENEFITS

- Compact RETOX® RTO footprint
- Rapid installation time/minimal space
- Low profile modules for roof/indoor mounting
- Low electrical/fan H.P. operating costs
- High thermal efficiency-95%
- RETOX® RTO turbulent flow media costs 1/5 that of laminar flow structural blocks/monoliths
- Many standard sizes to meet most VOC abatement requirements
- Extremely low capital and energy costs
- All RETOX® RTO drawings are AutoCAD ready
- Minimal energy costs-a true 95% efficient RTO HX
- No NOX with flameless operation
- Saves 40-60% on gas vs. burner firing
- No burner combustion air blowers to operate
- Leak proof valves provide high VOC destruction up to 99+%
- 5 year warranty on valves/pneumatic actuators
- Debugged prior to field start-up
- Quality performance
- Remote diagnostics/analysis of system via modem free for life of RETOX® RTO
- Stores heat efficient inside of beds

RTO applications up to 25% LEL solvent loadings	• Allows rapid 1 hour cold start-up
Design temperatures up to 1700°F	• Versatile system operational flexibility with optional high solvent heat exchanger bypass
Adwest/Airex Oxidizer Experience	• VOC destruction up to >99%
	• Over 500 RETOX® RTOs worldwide/Proven mature RETOX® RTO Design
Adwest Turnkey installation packages	• Single source responsibility includes design, installation, ductwork, stacks, start-up and training
Zero internal maintenance with no internal moving metallic parts/adjustments	• No need to enter RTO for maintenance
	• All components accessible outside RTO
Optional RETOX® RTO puff capture system	• No internal metal sector plates to warp
	• Increases VOC capture efficiency

## BIO AUGMENTATION ADVANTAGES

### Introduction

Clean TeQ specializes in innovative solutions for pollution control and BioAugmentation range of products provides a cost effective solution for the control of odour in wastewater systems. The BioAugmentation system uses the established principles of “competitive exclusion” and “biological enhancement” to provide beneficial outcomes in many areas of wastewater treatment. The system uses only bacteria that are classified as Class 1 by the American Type Culture Collection.

The Bacteria are:

- Naturally occurring
- Non pathogenic
- Non Opportunistic

### Products and Applications

#### Bio GT

For grease traps and drain lines in restaurants and domestic areas, reducing odour and costly pump outs.

#### Bio ST

For septic tanks, increasing the treatment level of the system, decreasing odour and pump out intervals.

#### Bio IST

For sewer transport systems. Turns the transfer pipe into a wastewater treatment system and protect the assets against corrosion by sulphur-reducing bacteria.

#### Bio PS

For pump stations, reducing the maintenance requirements for degreasing equipment and reducing odour.

**Bio BSR**

For wastewater treatment plants reducing sludge volumes and oxygen requirements.

**Bio NP**

Utilised for the reduction of nitrogen and phosphorus in wastewater treatment plants.

**Bio COM**

Utilised in the food manufacturing industry, aiding the reduction of Biological Oxygen Demand and Free Oils and Greases.

**Bio PET**

For petroleum applications reducing BTEX, petroleum products (petrol, and engine coolants) and hydrocarbons in interceptors, bilge water and soils.

The BioAugmentation products are available in slow release tablets or controlled liquid dosing systems.

**BioAugmentation provides the advantages of:**

- ❑ Lower cost form of treatment
- ❑ Low capital cost
- ❑ Low maintenance
- ❑ Natural system in harmony with the environment
- ❑ Easily expanded when the requirement arises

**The Bioaugmentation delivery systems are:**

- ❑ Designed to suit the client's application
- ❑ Designed in a modular form, fully sealed with all mechanisms contained within the unit
- ❑ Are supplied with a delivery control system

Contact: David Glenn at [sales@cleanteq.com](mailto:sales@cleanteq.com) for further information

Source: [www.cleanteq.com](http://www.cleanteq.com)



# **APPENDIX A4**

**COLUMBUS ENGINEERING  
JET FAN ENHANCEMENT TECHNOLOGY**



# Columbus Pty Ltd

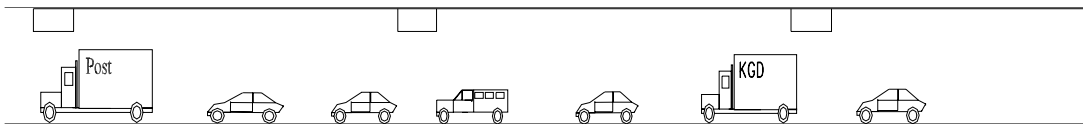
## The Problem

Many countries are building road tunnels to help with their traffic problems. This takes away the cars and lorries from the streets and moves them underground. What goes down must come up again. This refers to the vehicles but also to the pollution. Pollution effects people living at the tunnel exits and also the vehicle drivers. Both become sick.



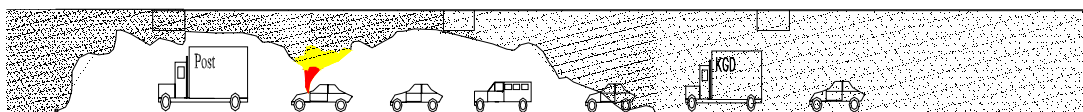
## The Answer

**The most practical and economic solution is to install a Jet Fan Filter System. This system cleans the air at the same time as the pollution is produced so improving visibility and drivers health.**



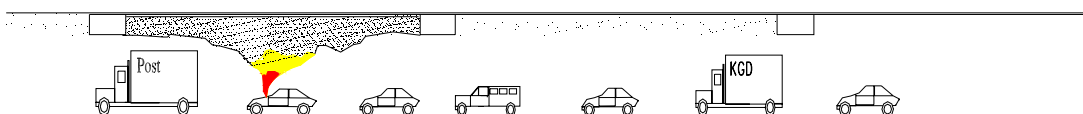
## The Problem

More and more vehicles are using tunnels. This increases the chances of having a fire in the tunnel. With a tunnel fire the major contributor to fatalities is smoke. With smoke in a tunnel people become disorientated and die through asphyxiation. Fire fighters cannot reach the fire due to the smoke.



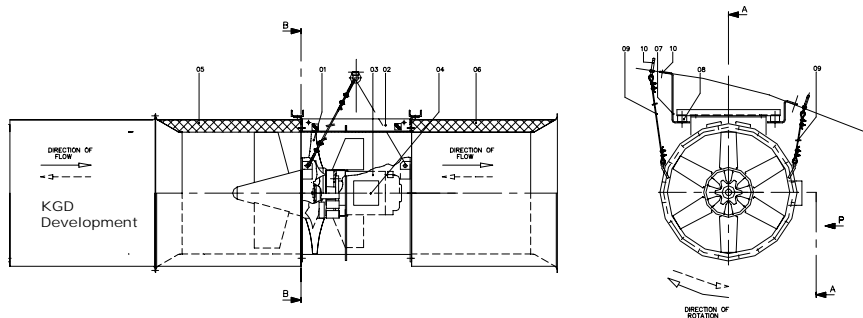
## The Answer

**With a Jet Fan Filter system installed the smoke is removed so that the drivers can find the exits and walk to safety. With a Jet Fan Filter system the fire fighters can access the fire to extinguish it and save life.**



# The Jet Fan Filtration System

## THE SOLUTION TO ALL TUNNEL PARTICULATE FILTRATION PROBLEMS



- ❑ THE JET FAN FILTER SYSTEM FIXES DIRECTLY TO THE JET FAN.
- ❑ THE JET FAN FILTER SYSTEM IS BOLTED TO THE TUNNEL ROOF. NO EXCAVATION REQUIRED.
- ❑ THE JET FAN FILTER SYSTEM IS REVERSIBLE.
- ❑ THE JET FAN FILTER SYSTEM CAN BE POWER FROM THE JET FAN DISTRIBUTION BOX.
- ❑ THE JET FAN FILTER SYSTEM REQUIRES ONLY A PERIODIC INSPECTION.
- ❑ THE JET FAN FILTER SYSTEM HAS THE HIGHEST EFFICIENCY VERSUS VELOCITY OF ANY OTHER FILTER (SEE HISTOGRAM).
- ❑ THE JET FAN FILTER SYSTEM CAN BE FITTED INTO EXISTING TUNNELS.
- ❑ THE JET FAN FILTER SYSTEM CAN BE FITTED INTO UNDERSEA TUNNELS.
- ❑ THE JET FAN FILTER SYSTEM HAS THE LOWEST INSTALLATION COST PER M<sup>3</sup>/S OF AIR CLEANED.
- ❑ THE JET FAN FILTER SYSTEM HAS THE LOWEST PURCHASE COST PER M<sup>3</sup>/S OF AIR CLEANED.
- ❑ THE JET FAN FILTER SYSTEM HAS THE LOWEST RUNNING COST PER M<sup>3</sup>/S

## **1 THE KGD JET FAN FILTRATION SYSTEM**

The KGD Jet Fan Filtration System consists of continuous ionisation electrostatic filtration units designed to fit onto existing ceiling mounted jet fans.

This unique design approach means that this form of particulate emission treatment can be installed in any road tunnel application involving the use of jet fans.

The purpose of this overview document is to highlight the key features and advantages of the system, and the potential relevance and benefit of the system to the RTA in the context of the current emission treatment ROI process.

## **2 ADVANTAGES OF THE SYSTEM**

### **2.1 Mounts to Existing Jet Fans**

KGD Jet Fan Filters can be mounted easily and quickly to existing jet fans, and are fabricated to match the dimensions of existing fan bodies. No additional civil or structural works are required.

### **2.2 No Impediment to Aerodynamic Flow**

By fitting to and matching the dimensions of existing jet fans, the KGD System presents virtually no additional restriction or impediment to airflow within the tunnel.

This feature, which is not shared by other ceiling or wall mounted precipitation systems, offers significant potential benefits in terms of overall energy efficiency, and in the management of emergency situations.

### **2.3 In Tunnel Treatment Capability**

The system offers an effective and cost efficient mechanism to remove fine particle pollution within the tunnel itself, and not only in purpose built by passes, at tunnel portals or in tunnel ventilation stacks.

### **2.4 Modular and Focussed Treatment Approach**

Overall emission treatment capability can be matched to individual tunnel situations by increasing or decreasing the number of filter units used.

High demand areas within tunnels can be targeted by the installation of incremental filter fans in those specific areas.

### **2.5 Filter Units Fully Reversible**

The filter fan units are designed to operate in a fully reversible manner, and can therefore adjust to any reversal of airflow through jet fans in changed or emergency operating conditions.

### **2.6 Filter Units Self Cleaning**

The individual filter units are self-cleaning, and designed so that all maintenance can be undertaken quickly and effectively by simple lane closures during off peak periods.

## **2.7 Energy Efficient**

The KGD Jet Fan Filtration System has been designed to operate with minimal flow restriction, and offers what we believe to be the lowest energy requirement of any particle precipitation system, in terms of the actual quantity of airborne particle removed.

## **2.8 Effective at High Flow Rates**

The KGD Jet Fan Filtration System has been demonstrated to remain effective at very high flow rates, and offers advantages in this respect over conventional electrostatic precipitation systems. Further information in this regard has been provided in Section 6 of this submission.

## **2.9 Highly Efficient**

The KGD Jet Fan Filtration System has been demonstrated in actual road tunnel conditions to deliver very high particle removal efficiencies for a wide range of particle sizes, and over a wide range of operating conditions and flow rates.

## **2.10 Synergistic with Other Treatment Technologies**

The KGD System operates on an “in tunnel” basis, in conjunction with existing jet fans. In this respect, the system is fully compatible with, and in fact potentially complementary to, any other emission treatment systems that might be used in tunnel by passes, at tunnel portals, or in tunnel ventilation stacks.

## **2.11 Cost Effective**

The low production, installation and operating costs of the KGD Jet Fan Filtration System combine to deliver effective net costs, on a performance basis, that we believe will be half or less those offered by alternative particle treatment systems.

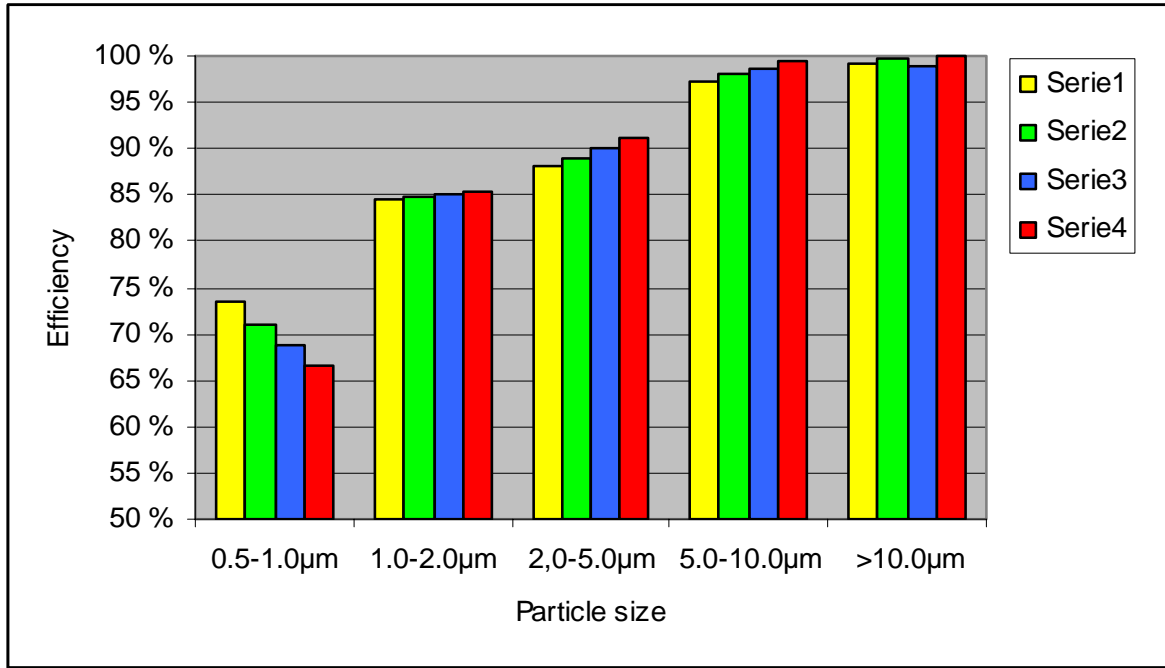
## **2.12 Can be Trialled easily and at Low Cost**

Because of its low installation cost, and its compatibility with existing tunnel structures and systems, the KGD Jet Fan Filtration System can be trialled in a very cost effective manner. Further details in this regard have been provided in Section & of this submission.

## **3 SYSTEM EFFICIENCY**

The KGD Jet Fan Filtration System has been trialled under road tunnel conditions in the Drammen Tunnel, Norway.

In summary, the following particle removal efficiencies were obtained:



**Figure 1 – Performance Data: Drammen Tunnel, Norway**

Series 1: 10m/s Series 2: 18m/s Series 3: 24m/s Series 4: 32m/s

	0.5µm – 1.0µm	1.0µm – 2.0µm	2.0µm – 5.0µm	5.0µm – 10.0µm	> 10.0µm
10 m/s	73.50%	84.40%	88.00%	97.20%	99.20%
18 m/s	71.10%	84.70%	89.00%	97.95%	99.60%
24 m/s	68.79%	85.00%	90.01%	98.71%	98.89%
32 m/s	66.53%	85.30%	91.03%	99.47%	99.90%

**Figure 2 – Summary of Performance Data: Drammen Tunnel, Norway**

#### 4 CONTACT DETAILS

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