The Efficiency of Particle Cleaning in Norwegian Tunnels

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ABSTRACT

In Norway, the Public Roads Administration has installed equipment for particle cleaning in 6 tunnels from 1990 to 1996. All tunnels have solutions based on the use of electrostatic filters. Three of the tunnels, where the purpose of the installations has been to obtain an improvement of air quality and visibility as well as a reduction of emission from the tunnels, have a bypass solution. In one of the tunnels the electrostatic filter has been installed in connection with the ventilation tower, hereby reducing emission from the tunnel.

In the last tunnel project including electrostatic filters, the filters have been installed in the ceiling. The air is thereby cleaned point by point inwards in the tunnel. In this tunnel three particle cleaning plants were installed in the ceiling. They were placed approx. 1 km apart. This particle cleaning system, a solution which we regard with great expectations, was primarily built with the purpose to improve visibility in the tunnel.

In the winter 1996 the Directorate of Public Roads engaged the Norwegian Institut for Air Research (NILU) to investigate the cleaning effect of a bypass solution. The Ekeberg Tunnel, where the particle cleaning plant is designed for a capacity of 250 m^3/s, was selected for execution of these investigations.

The measurements of particle concentrations based on weight were carried out using the NILU's two filter sampler, which measures particles with diameter < 10 µm (PM10) and < 2,5 µm (PM 2,5).

The measurements showed that the cleaning effect during the measurement periode for the above mentioned particle fractions varied between 90% and 95%. Consequently the obtained results show a cleaning effect equivalent to the effect which was theoretically estimated prior to the decision of installing the particle cleaning plant.

During the winter 1997 we are planning to make corresponding measurements of the cleaning effect of the tunnel ceiling plants in order to determine the extent of tunnel visibility improvement caused by these particle cleaning plants.

1. Experience from use of particle cleaning systems

So far, the Public Roads Administration has installed equipment for particle cleaning in five tunnels, from 1990 to 1996. All tunnels have solutions based on the use of electrostatic filters combined with mechanical filters.

At present, the following tunnels are equipped with particle cleaning plants:

- The OsloTunnel (installed in connection with the ventilation tower)
- The Granfoss Tunnel (bypass)
- The Ekeberg Tunnel (bypass) northbound
- The Ekeberg Tunnel (bypass) southbound
- The Hell Tunnel (installation in the ceiling)

The purpose behind installing particle cleaning systems in these tunnels varies slightly:

In the Oslo Tunnel the purpose was to reduce the particle pollution on the environment, in the tunnel's neighbourhood.

In the Granfoss Tunnel and the Ekeberg Tunnels the purpose was to reduce the emission from the tunnels as well as to improve visibility inside the tunnels.

In the Hell tunnel, which is the only one of these tunnels with two way traffic, the purpose was to improve visibility in order to obtain better driving conditions and traffic safety.

I will present a more detailed description of the tunnels in question and describe the solutions which have been selected for particle cleaning.

1.1 The Oslo Tunnel

The Oslo Tunnel is a highway tunnel under the centre of Oslo, consisting of two tubes with six traffic lanes.

The length of each tube is approximately 1800 m. The annual average daily traffic today is approximately 70000 - 80000 vehicles/day. Both tunnels have a longitudinal ventilation system, with a vertical shaft at the end of each tube to reduce emission of polluted air from the tunnel portals.

The ventilation capacity is about 1000 m^3/s in each tube.

In connection with one of the ventilation towers, electrostatic filters have been installed to extract particles before the air is emitted through the ventilation tower. The principle is illustrated in Fig. 1.

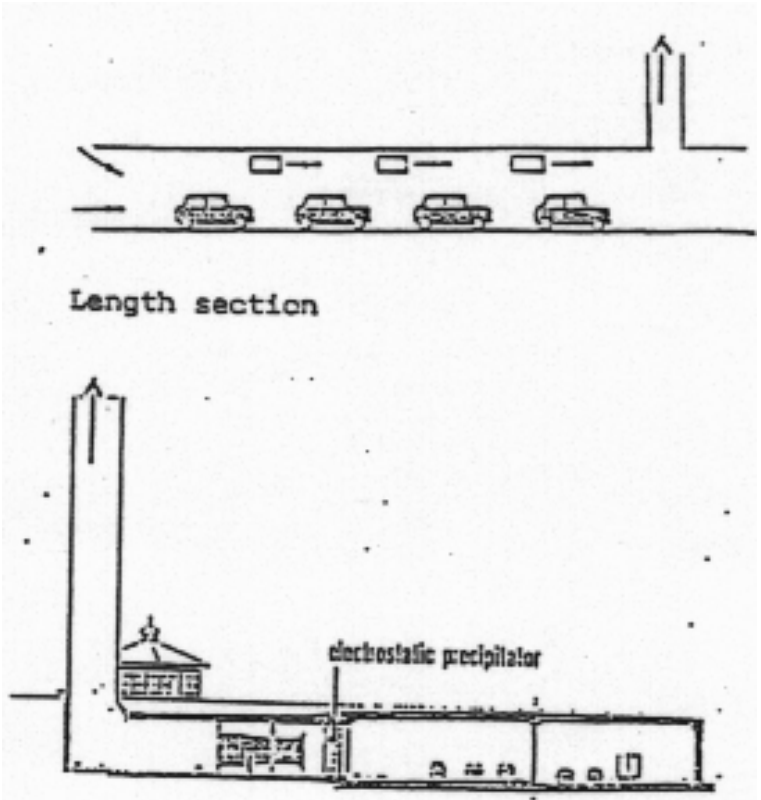

Fig. 1. Principle for installation of electrostatic filters in the Oslo Tunnel.

The capacity of the air cleaning system is 600 m^3 air/s.

In order to improve the air quality in the city, polluted air from one tube is cleaned before entering the tower. Even with ventilation towers for discharge of polluted air, the spread of particles is a problem in the outside area around the towers.

Since the opening of the tunnels, the pollution has been monitored into and out of the tunnel. We have also monitored pollution intensity at different points in the city. These measurements have given information on the concentration of particles before and after the tunnels were opened. Experiences so far veryfy that the cleaning system has a positive effect on the area around the ventilation tower. The test in the Oslo tunnel shows that it is very effective to extract particles before emission through the ventilation tower. This in turn implies a clear positive effect on the environment surrounding the emission point.

1.2 The Granfoss Tunnel and the Ekeberg Tunnels

In these tunnels a bypass inside the tunnels has been selected for extraction of particles instead of a ventilation tower. This solution, where the air is cleaned inside the bypass tunnel, has considerable advantages compared to the construction of a ventilation tower. The project planning procedure is very much simplified without the need to implement a ventilation tower for emission of polluted air.

The Granfoss Tunnel is approximately 1000 m long, with an AADT of 15000 - 20000 vehicles/day.

The Ekeberg Tunnel is approximately 1500 m long with an AADT of 50000 vehicles/day.

The Granfoss Tunnel and the Ekeberg Tunnels each have two tubes with one way traffic.

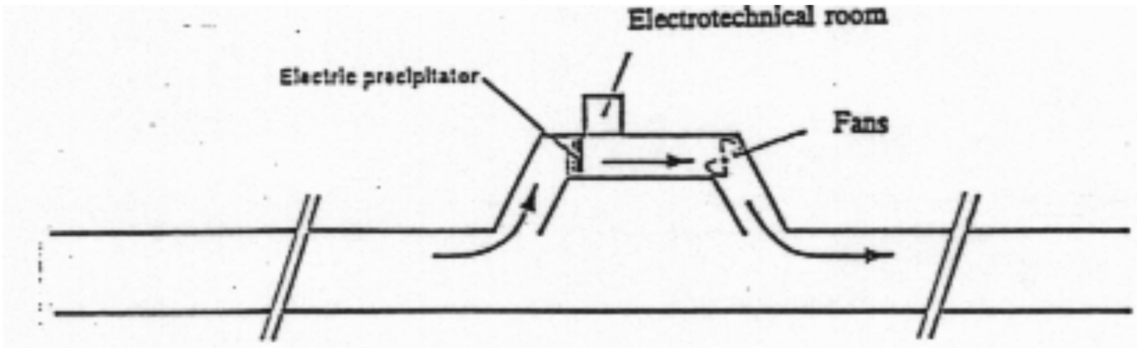

Fig. 2 The principle for a bypass solution selected in the Granfoss Tunnel and the Ekeberg Tunnels

The main purpose behind selecting this type of solution in the Granfoss Tunnel as well as in the Ekeberg Tunnels, was to achieve better visibility in the tunnels, and to reduce the pollution and emission of particles to the area surrounding the tunnel portals. In all three tunnels, the length of the bypass behind the electrostatic filter is designed to have sufficient space for the installation of a plant for clearing of nitrous gases.

1.3 The Hell Tunnel

Research till now on different electrostatic filters shows that certain filters have a high extraction rate with an air velocity as high as 7 m/s. By increasing the air velocity through the filter, without renunciation of cleaning effectiveness, the necessary filter area to clean the same volume of polluted air can be reduced. This will reduce the construction and installation costs. Increased allowable air velocity will in some cases also make it acceptable to install the cleaning units in the tunnel ceiling, provided that the air volume to be cleaned is not too large.

The Hell Tunnel is 3880 m long, has two-way traffic in one tube, and a traffic volume of approximately 10000 vehicles/day.

In this tunnel electrostatic filters were installed in the tunnel ceiling at points along the tunnel as shown in Fig. 3.

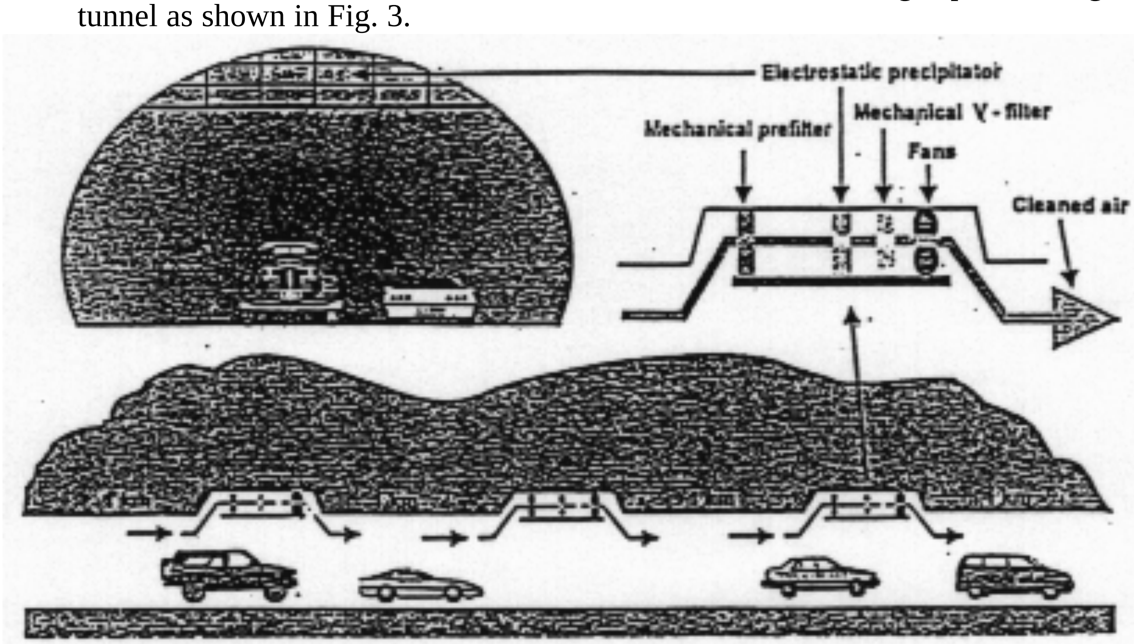

Fig. 3. Principle for installing electrostatic filters in the Hell Tunnel.

Cleaning equipment is installed at three points along the tunnel. The distance between the stations is approximately 1000 m. The capacity is 100 m^3 air/s at each cleaning station. The air velocity through the electrostatic filter station is 7 m/s.

This solution has been selected with the purpose of improving the visibility inside the tunnel, but the solution will also reduce the emissions to the area surrounding the tunnel portal.

By an efficiency of 90% of the particles passing through the electrostatic filter we expect a practical extraction rate of 70% - 75% of particles in the tunnel after (behind) the cleaning station.

Measurements to decide the extraction rate by this solution will be made and completed during the winter/spring 1997.

2. Conditions, measurements and results of measurements of cleaning effect of electrostatic filters installed in the bypass solution in the Ekeberg Tunnels

2.1 The purpose of the installations

The purpose behind the installation of a particle cleaning system in the Ekeberg Tunnels was to obtain good visibility inside the tunnels and to reduce the emission of particle polluted air to the environment.

An alternative to a bypass solution was to construct a shaft to reduce the emission to the environment outside the tunnels. Even in this case it would be necessary to install equipment for particle cleaning.

In this case the best and most economic solution was to construct a bypass and it was decided to install two fans with a total capacity of 250 m^3/s that draw in air to the bypass. The amount of air through the bypass represents approx. 50% of the air volume in the main tunnel. The air stream in the main tunnel is caused only by the piston effect from vehicles driving at a velocity of 70 km/h (air volume 500 m^3/s).

Based on these conditions the reduction of particle concentrations in the tunnel at the exit of the cleaning circuit was calculated to be 45 - 47,5%. The reduction of particle emission on the environment close to the tunnel was calculated to be approx 40%. The bypass is situated approx. 500 m before the tunnel exit to improve visibility in the final 500 m of the tunnel. The calculations were based on the assumption that the efficiency of the filter was 90-95% for PM 2,5 - PM 10.

2.2 Measurements to investigate the efficiency of the particle cleaning equipment

In the winter 1996 the Directorate of Public Roads engaged the Norwegian Institut for Air Research (NILU) to investigate the efficiency of the electrostatic filters combined with mechanical filters installed in the Ekeberg Tunnels.

The measurements of particle concentrations based on weight were made using the NILU's two filter sampler, which measures particles with airodynamic diameter < 10 μm (PM 10) and < 2,5 μm (PM 2,5).

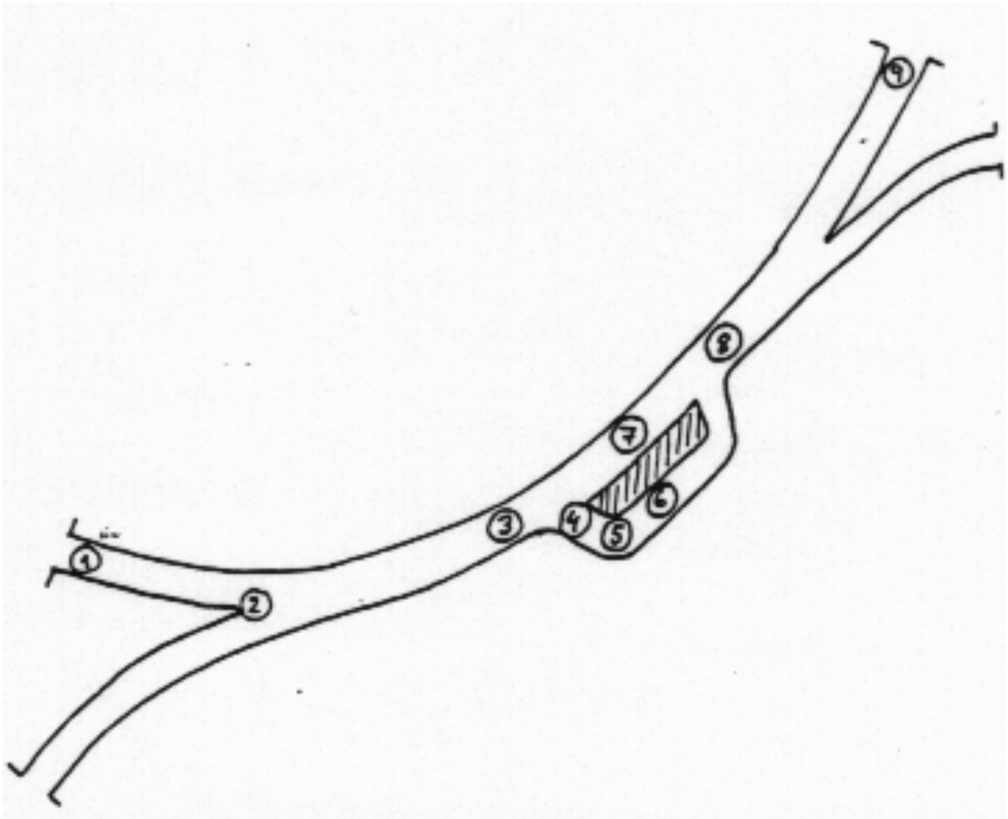

Fig. 4 Principle draft of one of the tubes of the Ekeberg Tunnel including measurement points

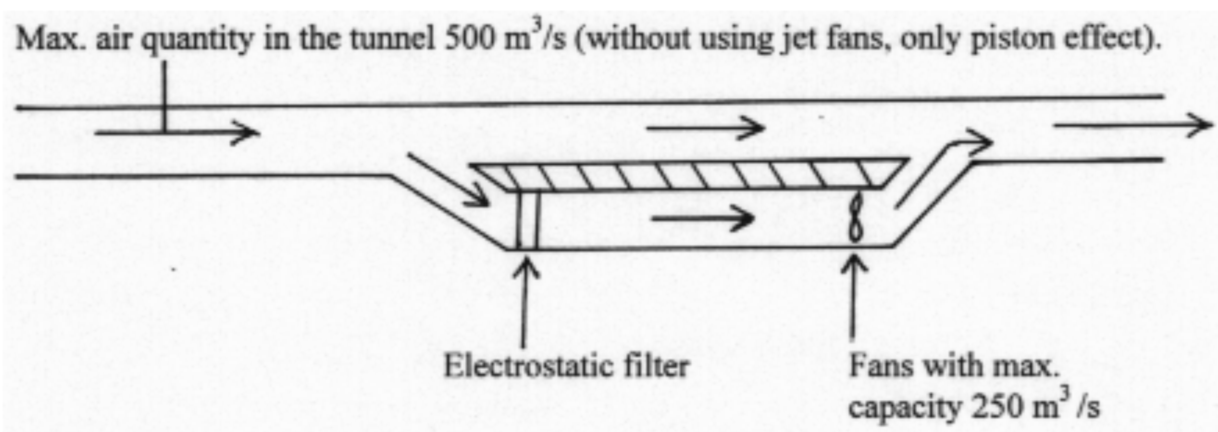

Fig. 5 A principle draft with air flows and air quantities in the tunnel and the cleaning bypass.

2.3 The results of the measurements

The efficiency of the filter was measured as the difference in particle concentrations in front of and behind the filter. This difference consequently serves as a gauge for the effectiveness of the filter.

In order to measure the cleaning effect of the entire cleaning bypass, the difference in particle concentrations between the entrance and the exit of the cleaning circuit was measured. This serves as a base for the effect of particle extraction with regard to visibility conditions for the drivers inside the tunnel and for emissions to the environment in the tunnel's neighbourhood.

Conclusions of measurements

Measurements of air flows and suspended dust particles concentrations in the air that have been made in one of the tubes of the Ekeberg tunnel verify that the electrostatic filter can extract up to 99% of the suspended dust particles at optimal conditions. The measurements also show, however, that the effectiveness of the filter declines by increasing air velocity through the filter and with the layer of particles on the collector plates. With an air flow of 270 m^3 through the cleaning circuit and a dust layer on each condenser sheet of approx. 1,7 g the collecting effect was approx. 90%. The building up of a dust layer on the collector plates to 1,7 g per sheet had occured after approx. 12 hours operating time of the filter. A max collection weight on each collector plate is approx. 10 g.

Measurements made of air flow during morning rush-hour traffic with high driving speed in the tunnel indicates that an increase of air flow through the cleaning circuit by the help of fans also increases the air flow in the main tube of the tunnel.

Maximum effect on the concentrations of emission of suspended particles at the tunnel portal was obtained by maximum fan capacity. The effect of the bypass solution 500 m before the tunnel end reduced the emission to the surroundings by 40%.

Compared to the estimated conditions of the cleaning circuit described in chapter 2.1, the efficiency of the filter by maximum exploitation of the fan capacity is in accordance with the estimated values of rush-hour traffic.