Full scale tunnel fire tests of VID Fire-Kill Low Pressure Water Mist Tunnel Fire Protection System in Runehamar test tunnel, spring 2009

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Synopsis.
VID Fire-Kill did in April and May 2009 conduct a series of large full scale Tunnel Fire Tests in the Runehammer Tunnel. The tunnel is an abandoned 9m wide, 6m high and 1600m long two driving lane rock tunnel located in Åndalsness on the west coast of Norway.
The fire tests involved diesel pool fires and solid class A fires with potential heat outputs of up to 100 MW. Three 20m long nozzle pipe protection sections of the VID Fire-Kill Low Pressure Water Mist Tunnel Protection System were installed in the centre line of the tunnel ceiling. Water mist from the nozzle pipes was manually released in the centre of the tunnel when the water pumps were turned on and water at 10 bar, water pressure was applied to the nozzle pipe line. By using a manual system release method, the test fires were provided time to develope, and here by to test the protection system in large developed fires. All test fires were conducted by Sintef NBL. Sintef NBL did also conduct all measurements, data recordings and documentation of the tests and results.

It was observed, that the VID Fire-Kill Tunnel Protection System provides fast fire suppression in large tunnel fires involving hydrocarbons (diesel oil) and solid fires (Class A) with potential heat output of up to 100 MW. It was also observed that the protection system effectively cools the tunnel pipes structure and the air temperatures in the whole tunnel pipe, allowing fire fighters and rescue personal safely to enter the tunnel pipe at an early stage to rescue people and fight fires. It was also observed that the fire protection system prevented smoke backflow in the tunnel with tunnel ventilation air velocities of down to 2m/s.

Purpose of the tests
The purpose with the fire test scenarios were to investigate the level of fire protection which an installed VID Fire-Kill Low Pressure Water Mist Tunnel Protection System is capable of supplying in large scale tunnel fires with high potential heat outputs.

The fire protection parameters which were investigated was

- The degree of fire suppression concerning heat output from fires.
- The degree of fire protection concerning temperature management.
- The degree of fire protection concerning risks of fire spreading in tunnels.
- The degree of fire protection concerning smoke management.
- The degree of fire protection concerning required ventilation conditions
- The degree of fire protection concerning visibilities and CO, CO2 propagation.

VID Fire-Kill Tunnel Protection System.
The fire tests were conducted with nozzle pipes from three 20m long protection sections of the VID Fire-Kill Low Pressure Tunnel Protection System installed in the centre line of the tunnel ceiling. In

all test fires the nozzle pipes were manually activated to distribute water mist in the tunnel pipe at 10 bar water pressure.
The nozzle pipes were inside the tunnel connected to an 800m long 4" pipe connecting the nozzle pipes to the pump system outside the tunnel. The pump system consisted of two Grundfoss CR water pumps. The total pump capacity was 90 m^3/h at 10 bar water pressure. The pump system required a power supply of 60 amps. Only fresh water with no additives was used during the fire tests.

The VID Fire-Kill Tunnel Protection System is an active fire detecting and fire suppression system. The system is a modular built system. Each module is 18m – 20 m long and consists of two module parts.
Each system module contains:

- a supply pipe section,
- nozzle pipes with water mist nozzles
- An electrically activated control valve which connects nozzle pipes to supply pipe section.
- A heat protected electric control panel with power back-up and connections to electric supply and buss line for remote control and alarm and system monitoring
- Two electric flame detectors to monitor the tunnel zone section for fires and to provide fire alarms and if necessary activate the panel to operate the section control valve to open for water to be distributed from the water mist nozzles in the fire section and its two neighbour tunnel system sections. The flame detectors are designed to provide alarm on all fires, and only to provide activation alarm signal on fires which do not move.
- A series of thermo sensors for double knock fire detection. The panel process signals from thermo sensors to a fire dependent rise of heat pattern.

System module sections are supplied as fully assembled and fully tested units from the factory, ready for installation in the tunnel ceiling. The units are installed in the tunnel ceiling and flanged together to make a pipe line through the whole length of the tunnel. All electrical connections are heat protected, and monitored. All electrical connections are plug connections, making a simple and secure tunnel fire protection to install.
A variation of the system has video cameras fitted on the tunnel modules, which become active and transmit addressable pictures to a central computer when flame detectors in the protection sections activate. This allows the tunnel operators actively to decide on if it is necessary to activate the tunnel protection section system.
The section control valves are designed to stay open when activated unto manually closed from inverting the electric signal to the valves.
The VID Fire-Kill Low Pressure Water Mist Tunnel System operates with 10 bar water pressure. When activated, the tunnel protection system operates three sections of 18-20m to distribute water mist in a length of the tunnel of totally 54-60m (the system section where the fire is located, and the two neighbour sections). Three sections are necessary always to ensure that a fire is fully enclosed with the fire protection coverage.

Nozzle pipes installed in the test tunnel.
The VID Fire-Kill Tunnel Protection System installed in the Runehammar tunnel was simplified only to be the nozzle pipes with water mist nozzles.
The test fires were arranged at a known location in the test tunnel. And the test fires should be provided time to grow large before water mist was released, to see how the VID Fire-Kill Tunnel Protection coped with large developed fires.
Therefore the system installed did not include the fire detection and alarm systems. Also the test tunnel already had a 4" water pipeline leading from the tunnel entrance to the centre of the tunnel. Therefore the tunnel protection system applied in the tests did only include three Nozzle pipe sections with the water mist nozzles of VID Fire-Kill Low Pressure Water Mist Tunnel System.
The 3 x 20m nozzle pipes were joined together in one pipe line, which was installed in the tunnel roof centreline in the centre of the tunnel. The Nozzle pipe line was in two places connected to the 4" water supply pipe in the tunnel, and the supply pipe was connected to the pump systems with hoses outside the tunnel. Water was taken from an open fresh water reservoir.

Two Grundfoss CR pumps were with hoses connected to the water mains pipe in the tunnel pipe. The pumps were connected to a reservoir with two dip- pipes. The power supply to the pump system was 60 amps. The pumps total capacity was 1.5 m^3/min at 10 bar.
The system was manually activated by turning on the pumps.

The Runehammer test tunnel.
The Runehammar test tunnel belongs to the Norwegian Road Authorities. The tunnel is a rock tunnel without lining. It is located in Åndalsness on the Norwegian west coast. The tunnel is a two lane road tunnel. It was a part of the Norwegian road infra structure until a landslides brought the road leading to the tunnel down into the fjord below.
The tunnel tube is 9m wide 6m high and 1600m long. Inside the tunnel tube the original road tunnel ventilator system with two ceiling fitted ventilators are installed and functioning. The ventilators are installed approximately 200m from the tunnel entrance. The ventilator system has a capacity of 2m/s – 3 m/s depending on the outside wind conditions. The original ventilator system was active through the whole fire test scenarios, and was never turned off.

Test fires and set-up of test fires.
All test fire were located in the centre of the tunnel, 800m from both tunnel openings. Three fire tests were conducted. In all fire tests a target arrangement was installed downstream the test fire to show if the fire would have had the possibility to spread to other vehicles in the tunnel.
The tests:

1: Diesel fire with 6 diesel pools. Each diesel pool was 2m^2 large and had 0,5m high sides to shield the pool fires. Prior to the fire test the diesel pools were filled with 1.5m^2 diesel oil. Sintef NBL estimated the fully developed fire to have a potential heat output of 30 MW. The fire was ignited with gasoline on the diesel oil surface. The fire protection system was activated 4 minutes after igniting the fire and the temperature was 450ºC above the fire and the nozzle pipe.

2: Solid fuel Class A fire. 180 pcs. euro pallets were stacked on a concrete foundation 1m above the road. The fire was ignited at the front of the wood pallet pile with 4 x 1litre plastic trays positioned in the wooden pallets. Sintef NBL had estimated that the fully developed fire would have a potential heat output of 50MW. The fire protection system was activated 5 minutes after igniting the fire and the temperature was 950ºC above the fire and the nozzle pipe.

3: Solid fuel Class A fire. 360 pcs. euro pallets were stacked on a concrete foundation 1m above the road. The fire was ignited at the front of the wood pallet pile with 4 x 1litre plastic trays placed in the wooden pallets. Sintef NBL had estimated that the fully developed fire would have a potential heat output of 100MW. The fire protection system was activated 6 minutes after fire ignition, and the temperature above the fire and above the nozzle pipe was more than 1000ºC

Target arrangement for fire spread from test fires.
A target arrangement to show spread of fire from the test fire was made for each fire test. The arrangement consisted of a 200 litre steel barrow, positioned 3m downstream of the test fires, and a pile of 10 euro wooden pallets positioned 6m downstream of the test fires. The water temperature was measured during the fire tests, and the pile of wooden pallets was inspected for fire damages after each test.
In no tests conducted did the fire spread to the wooden pallets, and the maximum temperature measured in the water was <35 ºC.

Instrumentation.
40m upstream from the test setups: Temperatures and air velocities were measured at different heights above the road.
5m downstream from the test setups: Temperatures were measures 2m, 3m, 4m, 5m, and 6m.

700m downstream from the tunnel centre and 100 from the tunnel exit: Temperatures were measured 2m, 3m, 4m, 5m, and 6m. And air velocities were measured in different heights, and CO, CO2, O2 were measured.

Conclusion:

Risks of fires spreading in the tunnel.
Fires having a potential heat output of up to 100MW fires will not spread to other vehicles in the tunnel tube if a VID Fire-Kill Tunnel Protection System is installed in the tunnel.
The heat from a potential 100 MW large fire did only cause a temperature increase of 20ºC to the water in the steel barrel 3m downstream from the fire, indicating that a fuel tank 3m away from a fire will not burst from heat in tunnels where a VID Fire-Kill Tunnel System is installed.

Suppression of Heat Output from the test fires.
The VID Fire-Kill Tunnel Protection System extinguished the 6 x 2m² diesel pool fire within 30 sec after activation.
The VID Fire-Kill Tunnel Protection System provided fast suppression of heat out puts for both the potential 50MW and the potential 100MW solid fires.
Heat outputs from fires were calorimeter method measured in single point in the tunnel tube cross section 100m from the tunnel outlet. A location 100m from the tunnel outlet is influenced by the wind conditions outside the tunnel pipe. The long distance from the test fires to the location of the measuring station for CO2, etc. 800m. The point measuring method and the location of measuring of CO2 concentrations and air velocities to calculate heat output does therefore incorporate large potential risks and large uncertainties in the calculation of heat out puts from fires.
The assumed potential heat outputs of the test fires are based upon many previous similar test fires conducted by Sintef NBL. The assumed potential heat out puts of the test fires are therefore most close to the actual heat out puts of the tests fires than what was measured and calculated during the test fires. However the calculated values provide a good idea of the tunnel systems abilities to suppress tunnel fires heat out puts.

Temperature control.
In all test fires the activation of the VID Fire-Kill Tunnel Protection system the water mist provided an immediate drop in temperatures in the tunnel on all levels above the road.
In all test fires the protection system kept the temperatures below temperatures which could risk causing damages to concrete tunnel structures, and in all fire tests the temperatures 2m above ground was kept below 100Cº shortly after system activation not causing harm to people in the tunnel due to temperatures.

Smoke management upstream of the fires.
During the test-fires a smoke backflow along the tunnel ceiling was observed at the measuring post 40m upstream the fire. The smoke back flow air velocity was approximately 3m/s against a jet-fan type ventilation with a forced air speed of 2-3 m/s along the ceiling.
In all fires the smoke back flow disappeared, and the air flow returned to the original forced air flow of 2-3 m/s as soon as the VID Fire-Kill tunnel protection was released to distribute water mist in the vicinity of the test fires.

Conditions up stream fires.
During the 100MW fire tests, one hour after system activation, people entered the tunnel without breathing equipment or heat protection, to watch the burning fire a few meters downstream the burning test fire. This was possible because of a ventilation velocity of 2m/s – 3m/s and the VID Fire-Kill Tunnel protection system was active.
This proves that it possible for rescuing and manual fire fighting to take place at an early time in a tunnel fires in tunnels where the VID Fire-Kill Tunnel Protection system is installed.

Conditionings Downstream fires:

The Oxygen and CO and CO2 concentration was measured 100 from the tunnel outlet downstream of the test fires. In no test fires did the oxygen concentration drop below 19%. The steam from evaporated water mist did therefore not cause conditions with lethal low oxygen concentrations. During the 6 x 2m² diesel oil fire test visibilities 0m – 100m from the tunnel exit was recorded on video. A video camera was positioned on the road 100m from the tunnel exit, and lamps with light intensities were positioned on the road at distances of 10m, 20m, 30m, 40m and 50m from the video camera. The ventilation during the fire tests were 1-3m/s depending on the location in the tunnel and the tunnel cross section. The fire was extinguished 4 minutes after it was ignited, and the water mist was on 30min before the fire was extinguished. The video recordings showed that the visibility disappeared after 990 sec, and the visibility returned again after 5 minutes because the VID Fire-Kill Tunnel Protection System had extinguished the fire after 30 sec. and thereby stopped the smoke propagation.