

# TuDEM LEGIO

AUTOMATIC FIRE EXTINGUISHING SYSTEM  
FOR TUNNEL PROTECTION  
WITH SPREAD REMOTE CONTROLLED MONITORS





The devices and equipment of the system are protected among other by following patents:

- IT 000 1382038 del 30.09.2010
- IT 000 1387359 del 06.04.2011
- IT 000 1392070 del 09.02.2012
- IT 000 1396431 del 23.11.2012

by following utility Models:

- IT 276757 del 04.10.2013

by following patents under process:

- MI 2013A001117 del 03.07.2103
- MI 2013A001382 del 09.08.2013

by following utility models under process:

- MI 2013U000292 del 09.08.2013
- MI 2013U000034 del 24.01.2014
- MI 2013U000035 del 24.01.2014

Caccialanza & C. reserve the right to change at any time, without prior notice, any specification or feature of the system in order to continuously improve the product.



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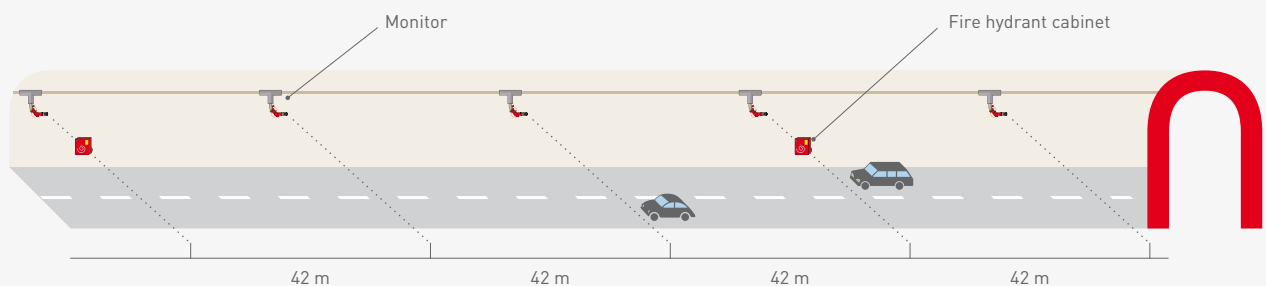


# Description and technical features of the system

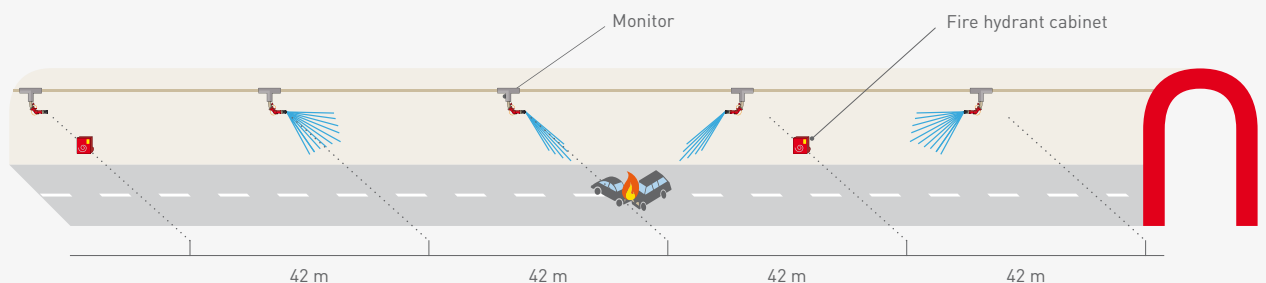
Innovating fire extinguishing system for tunnel fires, for fully automatic intervention or for remote operation from a remote Control Room. The system is based on the proven technology of fire fighting remote controlled foam/water monitors, worldwide utilized and appreciated for the fire protection in heavy risk plants. The fire extinguishing system for tunnel protection with remote controlled distributed fixed monitors consists of intervention and control stations with monitors directly installed and uniformly spaced along the tunnel at regular intervals of 42 m. The intervention and control stations consist of the electric remote controlled monitor with flow rate 1.000 lt./min. with on-off valve, the electric panel, the infrared flame detectors and two IP / TV cameras for visible and infrared light. The intervention and control stations are interconnected by:

- the main water (or foam premix) supply pipe (working pressure ~10 bar);
- the main electric power supply line;
- the serial bus for data transmission;
- the heat sensing cable for fire detection.

Monitors are electrically remote operated not only for elevation and rotation movements, but also for the nozzle movement from full jet to spray jet and for the opening/closing of the butterfly valve. Commands are transmitted independently to each monitor by means of a common serial bus, through a special cable providing also electric power supply of the units.



Monitor in stand-by condition.



Monitor in operating condition.



The fire protection system is integrated with a water pressurizing unit and with a foam proportioning system, consisting of a pumping station (normally with electric pump and Diesel motor pump) and a displacement liquid foam proportioner.

Alternatively to the displacement liquid foam proportioning unit, a balance pressure foam proportioner with related foam concentrate pump can be used.

The dimensioning of the foam storage and proportioning system depends on tunnel length and features. Usually the same foam supply system can be used for the 2 barrel vaults of the tunnel or for 2 adjacent tunnels.

It is important to consider that the extinguishing system with fire hydrant cabinets as required by law can be easily integrated in the proposed automatic extinguishing system with remote controlled monitors.

The fire hydrant cabinets are directly connected to the monitors main water supply line with regular intervals of 126 or 252 meters (with a step multiple of the distance of the intervention and control stations) and are usually equipped with a pressure reducing valve to reduce the water pressure at the manually operated branch pipes at about 4÷5 bar. In this case the pumping station is additionally equipped with a jockey pump to maintain the main water supply line permanently at a pressure of 5 bar for the hydrant cabinets.



## Automatic operation of the system

The automatic operation of the system is performed through a centralized main command and control panel installed in the Control Room of the tunnel or in any other technical room. For the automatic intervention, the extinguishing system is combined with a double technology fire detection system with linear heat detectors and infrared flame detectors installed along the whole length of the tunnel.

In case of detection of a fire, the system automatically selects the two monitors closest (upstream and downstream) to the fire and alarm zone and automatically aims the jet of the monitor on the fire.



The 2 monitors start spraying water or foam with a step-less adjustable jet from full jet (for maximum throw and extinguishing power) to narrow cone and wide cone fog jet (for maximum cooling effect) as shown here below:

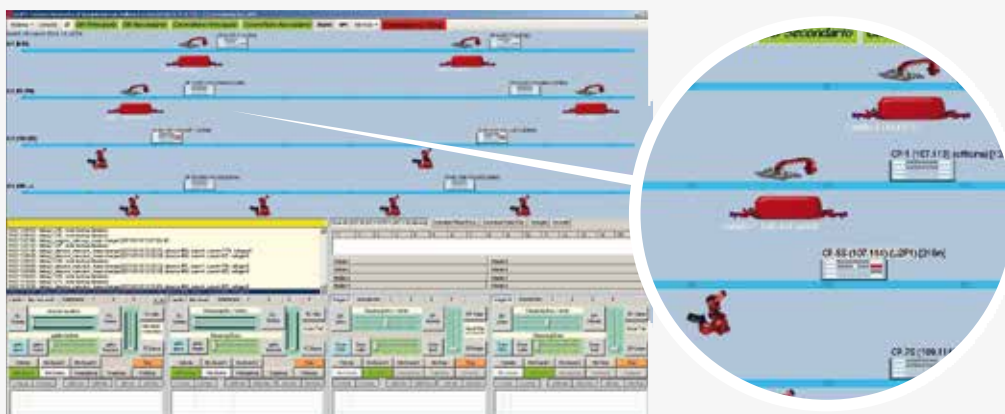


At the same time, if required, the two monitors positioned immediately upstream and downstream the 2 units involved in the fire extinguishing intervention start spraying water with a wide cone fog jet (with spray angle 120°) with cooling effect to drop the temperature inside the tunnel and for containing the fire smoke.

The whole typical process is reported in the scheme on page 4.

## Manual remote control of the system with joy-sticks from the panel in the Control Room

From the main command and control panel in the Control Room it is possible to control the situation in the tunnel by means of high sensibility IP / TV cameras for visible and infrared light mounted in the intervention and control stations, and to operate the monitors from remote with the joy-stick controller, aiming the jet of the monitors exactly on the fire.



This operation can be performed as final tuning of the automatic intervention of the system or on autonomous decision of the operator in the Control Room. In this case it is



sufficient to click with the mouse the exact point on the screen where the extinguishing operation is required in order to activate immediately the automatic selection procedure of the 2 monitors to be activated for extinguishing operation and of the 2 monitors to be activated for cooling and smoke containing operation. The IP / TV cameras for visible and infrared light mounted in the intervention and control stations allow the monitoring of the tunnel from the Control Room, with visible light or infrared technology depending on the local conditions and on the size of the objects to be observed.



Finally the system allows to best coordinate the operations of the fire brigades, showing continuously the situation of the fire area and of the surrounding.

## Local Manual Operation of the system with portable Radio Control Unit

In order to optimize eventual extinguishing interventions by specialized operators and by the Fire Brigades, in addition to the remote manual control from safe area, also a local control directly inside the tunnel is foreseen.

For this purpose is available a waistband radio control unit that enables manual selection of the required monitor and the manual direct control of its functions, besides eventual local correction of extinguishing operations in progress that have been activated by the main control panel. Like for the remote control, the movement control is carried out by means of a precision joystick and the system status data are visualized through LEDs and LCD displays on the waistband unit.



# Operational modalities of intervention

1

When the tunnel is in operation, the fixed monitors, positioned at regular intervals of 42÷50 m. along the tunnel wall, are in stand-by condition and are continuously monitored by the control system.

2

In the moment  $t = 0$  a fire starts inside the tunnel.  
The fire is detected by one or more detection systems installed inside the tunnel.  
TuDEM system processes the information from the area involved in the fire and selects the 2 nearest monitors (upstream and downstream the fire area).

3

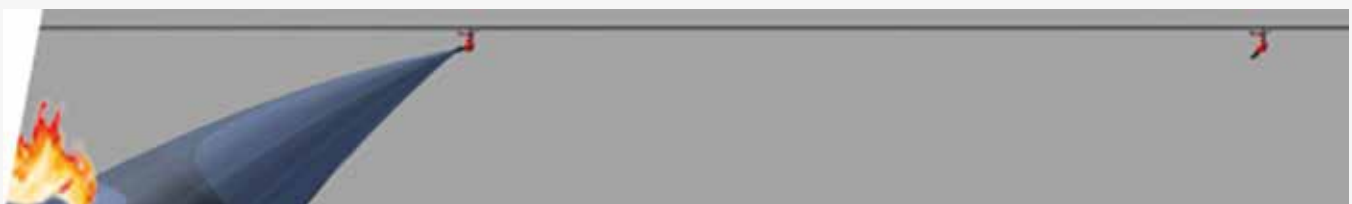
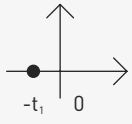
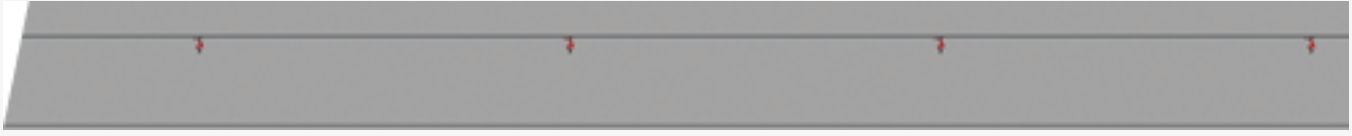
For a better representation the image scale has been changed.  
The 2 selected monitors upstream and downstream the fire area aim toward the fire. From the moment  $t = 0$  about 2' have passed.

4

The 2 selected monitors start the extinguishing operations.  
From the moment  $t = 0$  less than 3 minutes have passed.









5

An additional monitor, usually the monitor closest to the one already in operation, can be positioned and can start an additional cooling intervention.



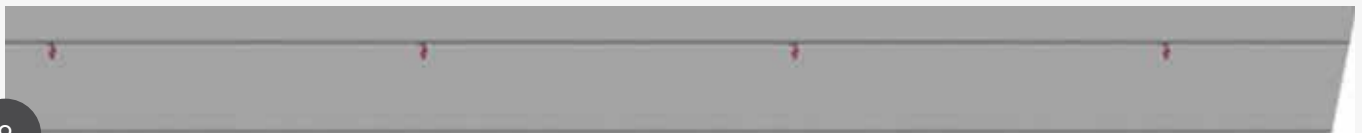
6

Also another monitor can be activated (like in the example on the other side of the fire) to start smoke containment operations.



7

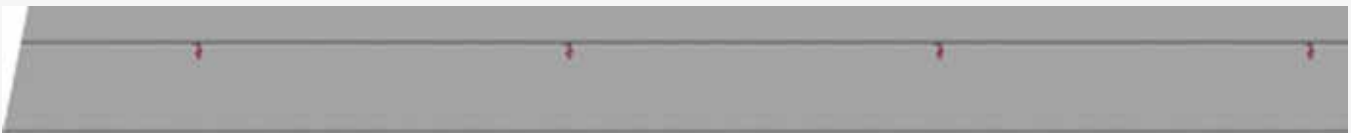
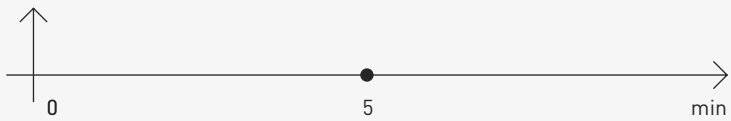
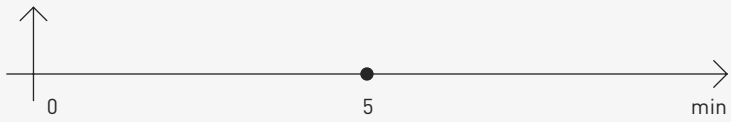
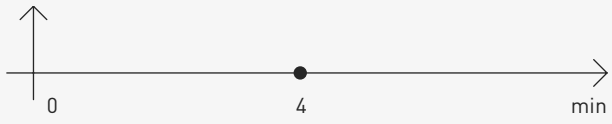
Alternatively to point 6) it is also possible (if more proper from an operating point of view) to choose a monitor from the other side of the fire to start smoke containment operations. Switching among the monitors in operation can be performed even during the intervention.



8

Extinguishing operations can go on for all the necessary time as the monitors are continuously provided with the required water and power supply. Delivery of each monitor can be independently stopped, started again and adjusted as needed. At the end of the operations monitors stop delivering and go back to their stand by position.





# Dimensioning of the system

Studies on the behaviour of fire development in tunnels performed by Research Institutes and Fire Brigades Laboratories are available in the literature, both supported by real tests and by mathematical models based on semi-empiric relations.

These studies, specially focussed on the time / temperature curves depending on the heating power of the different ignition sources, show that the maximum temperatures in a tunnel fire are reached after about 10 minutes, and that for the first 5 minutes the temperature inside the tunnel does not significantly differ from the temperatures reached by similar fires in open space.

When proper extinguishing actions start, the temperature increase stops almost immediately.

Following to the above, for tunnel fires an efficient extinguishing system must be activated in less than 5 minutes.

Of course, above indicated parameters are average values, and the specific value for each single tunnel must be determined with a risk analysis.

The dimensioning of the automatic fire extinguishing system with remote controlled monitors for tunnels protection must consequently assure an intervention time of less than 3 minutes from the start of the fire to the beginning of the automatic extinguishing action.

A time of less than 2 minutes is considered for the fire detection and for the validation procedures, and 1 minute is considered for the monitors to open the valves and to start the extinguishing operation.

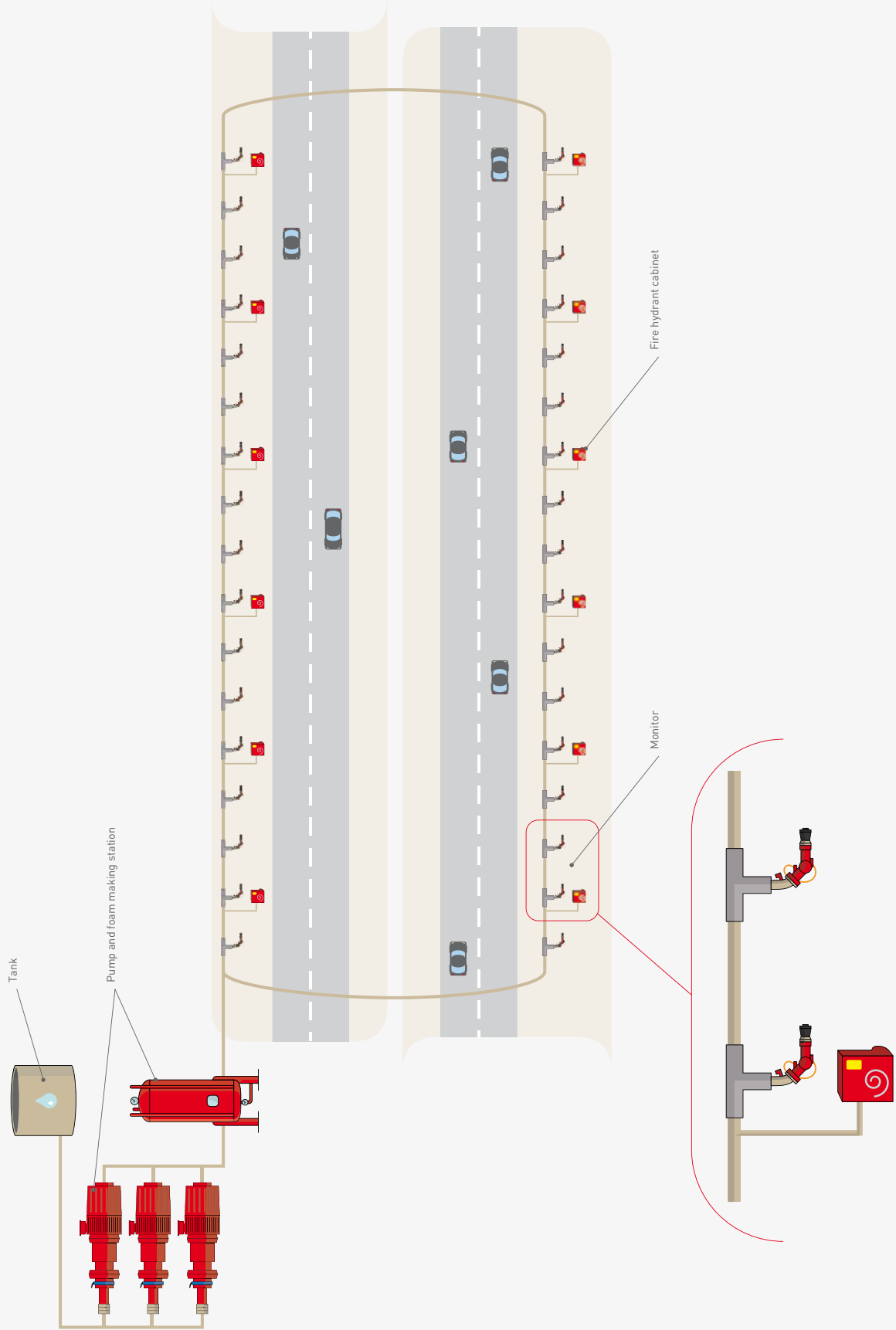
As already mentioned, the distance of the monitors along the tunnel is 42 meters.

In case of remote joy-stick operation of the system directly from the operator in the Control Room, the time of intervention can be further reduced.

Indeed, when the operator in the local or remote Control Room individuates a fire, he can immediately activate the extinguishing procedure (eliminating the time of automatic fire detection and validation), starting the extinguishing operation in less than 2 minutes.

The same happens if the operator decides to activate the extinguishing operation based on an alarm from a single fire detector, after checking the situation via the IP / TV cameras for visible and infrared light, without waiting for the redundant signal of the heat sensing cable (which is normally slower).





## Structure of the system

The main water (or foam premix) supply pipe is installed in elevated position at the wall along the tunnel, equipped with the main electric power supply line, the serial bus for data transmission and the heat sensing cable for fire detection.

Both the main electric power supply and the data transmission are carried out with a double loop.

The intervention and control stations are mounted along the tunnel with a typical spacing of 42 m.

The below picture shows the panel installed in each intervention and control station.

These points are the backbone of the fire detection subsystem, with regard both to the flame detectors (2 flame detectors mounted at each intervention and control station, oriented to the 2 directions of the tunnel) and to the heat sensing cable, divided into different functional sections distributed along the tunnel.

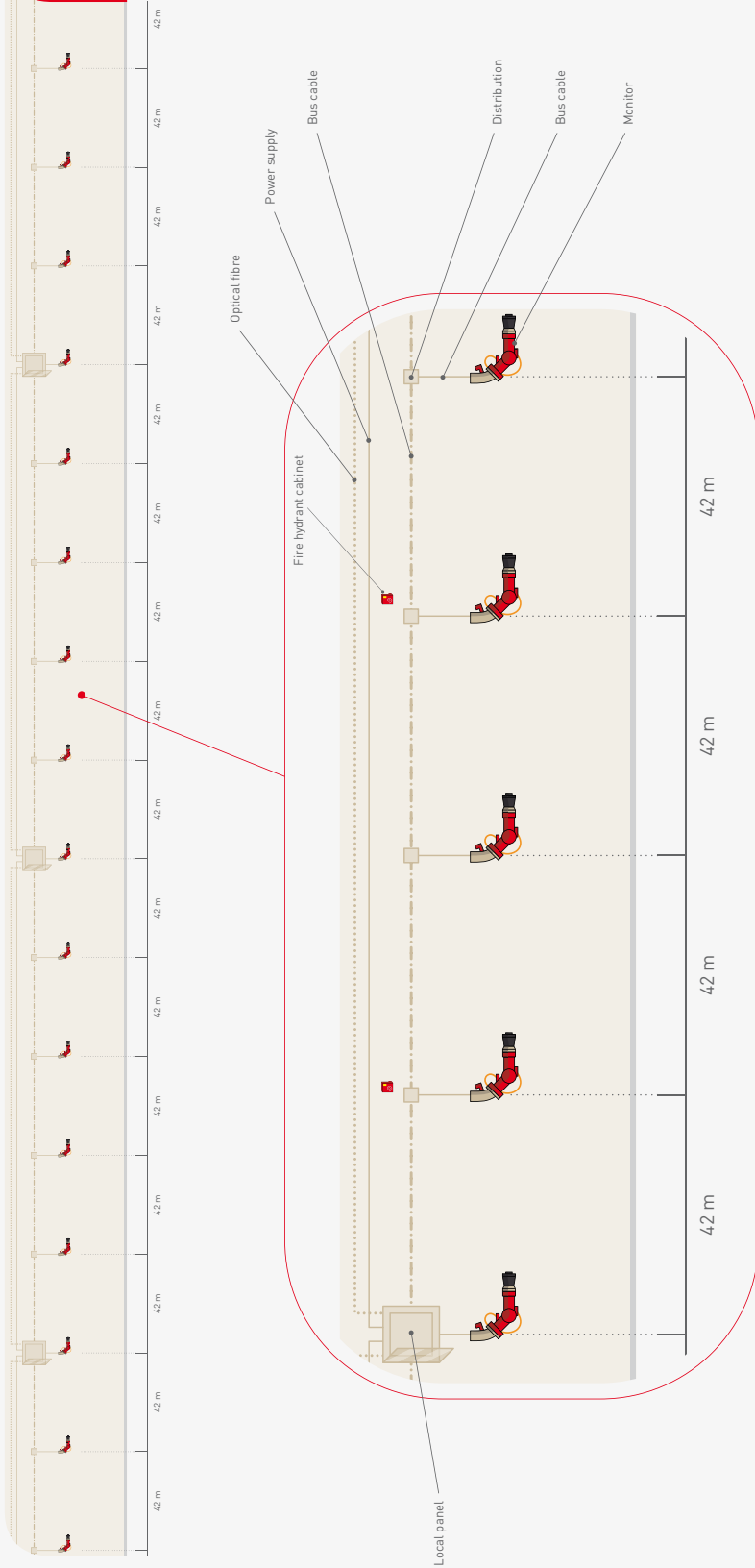
The signals of the fire detectors are processed in protected wall-mounted panels installed along the tunnel in each intervention and control station, where additional fixed monitoring cameras, both for visible and infrared light, can be interfaced if required. The same panels also provide the power supply to the remote controlled monitors and to the related remote controlled on-off valve for start or stop of the water or foam stream. The monitors are dimensioned for a specific water / foam flow rate of 1.000 lt./min. each, and following much higher than the total specific flow rate of any mobile unit or fixed spray system normally used for extinguishing operations inside tunnels.

The total water discharge of the remote controlled monitors system is nevertheless similar to the flow rate required for other fixed spray systems for tunnel protection, however this system allows to concentrate the full available water or foam stream exactly where required on the fire, instead of dispersing the extinguishing agent flow rate with uniform distribution along longer sections of the tunnel. The scheme on page 10 shows the typical water distribution of the system, including also the fire hydrant cabinets as required by law. The scheme on page 12 shows the typical electric and signal connections with the redundant double loop, to assure 100% functionality of the system in case of first failure in any point of the tunnel.



A2 EI monitor with nozzle and valve.





## Features of the fire extinguishing system with remote controlled distributed fixed monitors

The high performances and peculiar features of the fire extinguishing system for tunnel protection with remote controlled distributed fixed monitors and of the intervention and control stations can be summarized as follows:

- compact dimensions for fitting in the available spaces of motorway and railway tunnels;
- possibility to be installed and to work in any position (horizontal, vertical, reclined) in the tunnel vault;
- high reliability of all functions;
- reasonable costs;
- self check and transmission of position identification and working position, specific design for operation with water and with foam.

Parameters	Description
Max. length of the tunnel	without any limit
Distance between stations	typically 42 m, max. 500 m
Panels positioning interval	typically 250 m, max. 500 m
Number of actuators per monitor	5
Panel (primary / secondary) line voltage	230V/50Hz
Motor voltage (power / control)	24V d.c.
Solenoid valve voltage	24V
Main cables flame resistance	180 minutes according to IEC 60331 - 60332
Monitors number	1 per station
Monitors flowrate	1000 lt/min (each)
Max. spray angle	120°
Nominal pressure at nozzle	7 bar
Max. range of jet / nominal flowrate	52 m
Thermal passive protection	thoroughly metallic construction
Thermal active protection (cooling)	nozzles with flowrate 4lt/m <sup>2</sup>
Dimensions (in standby condition)	700Lx300Px600Hmm
Internal bus can open	according to CiA401 – CiA402
Ethernet communication protocol	according to IEEE 802.3
Monitor positioning feedback	double (elevation and rotation) encoder with relative value
Operation	automatic/semiautomatic/manual remote and local control
Correspondence with D.P.R. n. 151 dtd. 1.8.2012	integrated with fire hydrant cabinets at intervals of 126 or 252 m
Manufacturer	Caccialanza & C. Srl





## System reliability

The world wide proven extinguishing capacity of the automatic fire fighting system with remote controlled monitors is combined with the highest reliability of its components, considering the particular conditions where the fire fighting intervention must be performed.

To assure the highest reliability, redundancy has been applied to all critical parts of the system, for which not only the best materials and components available on the market have been selected, but also the most updated and reliable technology of monitoring, communication and check procedures have been adopted.

In particular for the data transmission a TCP/IP system has been selected, in order to allow the direct use of already existing communication structures or future structures to be realized for the remote transmission of alarms, commands and controls to the centralized Control Rooms of the tunnel without additional costs.

The system is therefore designed to be redundant in all its features:

- extinguishing operation by means of 2 monitors on the 2 sides of the fire (1 monitor is sufficient for extinguishing the fire),;
- the monitors approach the fire from 2 different sides;
- the power supply of the intervention and control stations is performed in a loop; therefore it is possible to supply separately and independently the 2 sides of any area involved in the fire;
- the data transmission (both via optical fibre and copper cable) is performed in a twin loop, separately and independently for the two sides of any area involved in the fire.

## Easy system installation

The automatic fire extinguishing system for tunnels protection with remote controlled distributed fixed monitors can be easily installed in new or in existing tunnels, without need to stop the tunnel traffic during the installation works of the system.

It can be installed in motorway tunnels, railway tunnels and in underground lines.



## Maintenance

Like all fire protection systems (as required by law), the automatic fire extinguishing system for tunnel protection with remote controlled monitors needs periodical maintenance.

The rules require that all main and peripheral components of a fire protection system are subject to scheduled maintenance and periodical functional tests.

Maintenance activities on the system are particularly easy because:

- all system components are permanently monitored by the central control panel with immediate signalisation and record of any problem;
- most of the components are mounted in the intervention and control stations, so that the maintenance can be easily carried out without stopping the tunnel traffic.

Finally, no relevant pipe reduction or small size calibrated orifice are provided in the whole system, which items are particularly sensitive to impurities in the fire water and require special accurate maintenance interventions to assure their proper operation.



## Applications of the system for ordinary monitoring and maintenance activities in the tunnel

Beside the main fire protection function, the automatic fire extinguishing system with distributed fixed remote controlled monitors can be utilized also for different purposes, such as monitoring and maintenance activities during the ordinary operation of the tunnel. The monitors installed along the tunnel can be operated singularly and in the required sequence, and can be oriented continuously and in each direction by means of the remote control according to the requirements of the different operations.



The IP / TV cameras for visible and infrared light installed in the intervention and control station along the tunnel can be used to check traffic and maintenance activities without any extra cost for installation and maintenance of these cameras.

The monitors can be used for cleaning activities (washing of the internal tunnel surfaces) or anti-pollution activities (dilution of dangerous liquids spills) wherever required along the tunnel, moving them by means of the remote control system and spraying specific detergent or solvent liquids properly admixed to the water. The intervention and control stations can be equipped with sensors for check of the air pollution (CO, etc.) or for check of explosive atmospheres in the tunnel, for continuous working and monitoring both during ordinary traffic conditions and in emergency conditions.

## Results of performed tests

The pictures here below shows some sequences of the tunnel tests.

The extinguishing tests have been performed in Santa Croce Tunnel - Strada dei Marmi (Carrara) and in the Test Tunnel of the Italian Fire Brigades' Training Centre in Montelibretti (Roma) as well as in the Gran Sasso Tunnel on the highway A24 between Aquila and Teramo.





Motorway Tunnel in Montelibretti (car fire)





Motorway Tunnel in Montelibretti (pool fire)



Underground Tunnel in Montelibretti



A24 motorway tunnel of the Gran Sasso



# Technical Notes

For description of performances and features of Caccialanza fire extinguishing systems for tunnel protection with remote controlled monitors, please refer to the following specific brochures:

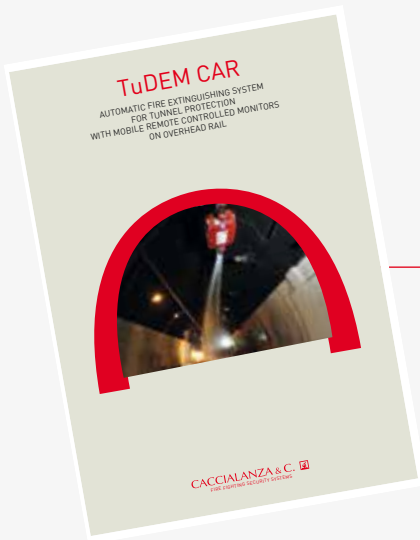
**PERFORMANCES TuDEM**  
PERFORMANCES OF THE  
AUTOMATIC FIRE EXTINGUISHING  
SYSTEM FOR TUNNEL PROTECTION  
WITH REMOTE CONTROLLED MONITORS

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**TuDEM CAR**  
AUTOMATIC FIRE EXTINGUISHING SY-  
STEM FOR TUNNEL PROTECTION  
WITH MOBILE REMOTE CONTROLLED  
MONITORS ON OVERHEAD RAIL

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**TuDEM ARIANNA**  
SIGNALISATION AND VISUAL GUIDE  
INTERACTIVE SYSTEM  
FOR EVACUATION ROUTES  
IN TUNNELS AND CONFINED AREAS

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## Main essential features of the system

The Automatic Fire Extinguishing System for Tunnels Protection with Mobile Remote Controlled Monitors on Overhead Trailer fully complies with the main essential features of a fire fighting system designed to extinguish tunnel fires as follows:

- high reliability of the extinguishing intervention;
- use of the most efficient fire fighting technology available for the specific class of fires and in particular for tunnel fires;
- relevant reserve (over sizing) of the specific required extinguishing flow rate;
- possibility to continue the extinguishing intervention without time limitation;
- automatic activation of the system without operator's direct intervention;
- possibility for the operator to take over the fire fighting operations from a remote safe area (Control Room), optimizing the extinguishing system performances;
- possibility to install the system for protection of motorway tunnels, railway tunnels and underground tunnels;
- automatic continuous self-diagnosis of the system status, both in stand-by and in working conditions;
- high reliability of the whole system;
- possibility of easy mounting of the system minimizing the installation activities (for existing tunnels);
- minimizing of the ordinary maintenance interventions and of the related costs;
- minimizing of the detail design for the different installations;
- standardization of the ordinary maintenance focused on few components, realized to be easily interchangeable.



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