

An Integrated Safety/Security Video Image Detection (VID) System for Road Tunnel Protection

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INTRODUCTION

Road tunnels face both fire safety and security challenges because of their complex infrastructure, fire hazards produced from traffic accidents and potential terrorist threats. Interest in the use of the automatic video image detection (VID) system for road tunnel protection is increased, because of its quick response to the fire or security incident, and real time video images for use in monitoring events, and in guiding evacuation, rescue and firefighting. Many tunnels are already equipped with VID systems for traffic managements and for security protection. Recent studies conducted by the Fire Protection Research Foundation (FPRF) at NFPA also showed that the VID fire detection system was one of promising detection technologies for the use in road tunnel protection [1]. As a relatively new technology, however, only a number of VID systems for either fire safety or security are available in the market [2] and the functions of fire safety and security are not integrated in the VID systems. In addition, previous FPRF studies recommended that efforts are needed for the VID fire detection systems to improve their detection and monitoring capability, and to reduce nuisance alarms produced in tunnel environments [1].

Recently, a new integrated safety/security VID system (AlarmEye®) was developed by InnoSys Industries Inc. [3]. It has been listed by UL as a VID flame/smoke detection system. Its fire detection capability and reliability in tunnel environments were evaluated in a research tunnel facility with dimensions of 120 m long, 12 m wide and 7 m high, following the China National Standard “Technical Condition for Fire Detection Systems in Road Tunnel.” This paper briefly describes this new integrated safety/security VID system. The fire test results conducted in the research tunnel facility are reported.

AlarmEye® SAFETY/SECURITY VID SYSTEM

The AlarmEye® VID system can act as an independent fire detector in which both the video processing and alarm algorithm execution are performed at the detector. It can also be used as a centralized detection system, in which up to eight video cameras are connected together and processed in a computer unit. The AlarmEye® detector consists of one color camera, one IR camera, one IR light source, image capture and pre-processing, and digital signal processor (DSP) (Figure 1). The optical flame sensor, as an additional detection option, can be combined with the detector.

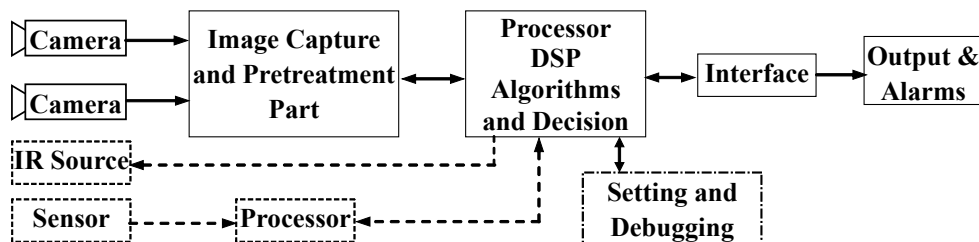


Figure 1. Block Diagram of a AlarmEye® VID system

Compared to conventional VID systems, the AlarmEye® VID system can extract more fire/environment information available from its multiple image sources to quickly and reliably detect a fire based on either smoke or flame signal, and to minimize nuisance/false alarms in tunnel environments (Figure 2). It divides its field of view up into 16 sub-zones: key surveillance zones for close monitoring and non-surveillance zones that may have potential false/nuisance sources or very low possibility for occurrence of the fire or security incident. The system can operate under all weather and light environments, including in the dark by using its IR light source. Its detection distance can be up to 110 m.

The AlarmEye® VID system can provide security protection and traffic management for road tunnels with its high quality multiple image sources and intelligent image and behaviour analysis. The system can monitor and count moving vehicles for congestion management. It can recognize inverse driving and stopping vehicles, and pick up any suspicious fallen or left objects. It can also provide drivers and pedestrians' information, track their movement automatically, and prevent them from entering into forbidden areas (Figure 3). The system can immediately notify monitoring personnel for traffic incidents, any abnormal traffic and human behaviour, and trespassing/intrusion.



Figure 2. AlarmEye VID system working in a road tunnel



Figure 3. AlarmEye VID system for security protection in a road tunnel

TUNNEL TEST FACILITY AND FIRE SCENARIOS

A series of full-scale fire tests for evaluating the performance of the AlarmEye VID system in tunnel environments were conducted in a research tunnel facility (Figure 4). The test tunnel has the same structure, configuration, and facility as those in Shanghai Yangzi River Road Tunnel. Its dimensions are 123 m long, 12 m wide and 6.7 m high. It can provide a uniform longitudinal air flow up to 5 m/s with a fan system. The smoke in the tunnel can be vented out through mechanical fan systems installed at the end top of the tunnel. Thermocouples, heat flux meters and air velocity meters were installed at the tunnel. They were used to monitor fire test conditions.

Fire scenarios in the tests included small unobstructed pool fires, pool fires located underneath, behind and inside the vehicle, stationary vehicle fires and small moving vehicle fires under wind speeds ranging 0-5 m/s. The fire sizes in the test series varied from 125 kW to 1750 kW, and fuel types included gasoline, wood crib and plastic foam. The fire source was placed respectively at eight locations in the tunnel ranging from 55 m to 110 m to VID detectors. These fire scenarios were considered representatives of the majority of tunnel fire incidents and are recommended in the FPRF tunnel research program [1] and China National Test Standard for road tunnel protection.

The impact of tunnel environments on the performance of the VID systems was also investigated in the test series. The test conditions included flashing lights on service vehicles, headlights of the vehicle at a different distance from the detector, and obstructed contamination to the camera window produced by dust, oil, water mist, droplets, condensation and frosting, as reported in the reference [3].

TEST RESULTS

Two unobstructed gasoline pool fires with dimensions of 0.3 m x 0.3 m and 0.6 m x 0.6 m were placed respectively at different locations in the tunnel. The wind speed in the tests was ranged from 0 to 5m/s. The VID system was able to quickly detect small unobstructed gasoline pool fires up to a detection distance of 110 m. Its detection time was ranged from 8 to 26 seconds. The response of the detector to the unobstructed liquid fuel fire was mainly based on its flame characteristics. As a result, its detection capability was not affected much by the size of the fire and changes in the direction distance under non-ventilation conditions. With longitudinal airflow in the tunnel, the flame size shown in the detector became small as the fire plume tilted toward the ground. However, the flashing of the flame produced by airflow was increased. The airflow had no impact on the detection capability of the VID system when the fire source was located at the distance of up to 90 m from the detector, but its detection time was increased at the detection distance of 110 m under strong airflow at 5 m/s.

The VID system also quickly detected a 0.6 m x 0.6 m gasoline pool fire placed inside the vehicle with detection time ranging 6 to 25 seconds when the fire source was 50 m away from the detector. The response of the detector to the fire was mainly based on its flame characteristics, as the fire was developed quickly and the flames were stretched out the vehicle.

Three tests were conducted with two different sizes of gasoline pool fires located under a medium size of the vehicle (Figure 5). The pan sizes were 0.6 m x 0.6 m and 1.0 m x 1.0 m. The wind speed was ranged from 1.5 to 5 m/s. It was challenge for the VID system to detect the small pool fire located under the vehicle with airflow in the tunnel as the flames and smoke were confined by the vehicle body. The response of the VID system to small concealed pool fires was mainly based on the smoke characteristics produced by the fire. It took 70 seconds for the detection system to detect a 0.6 m x 0.6 m gasoline pool fire under the vehicle at wind speed of 1.5 m/s. Its detection time increased to 95 seconds at the wind speed of 3 m/s. For the large 1.0 m x 1.0 m pool fire, the VID system quickly detected the fire at 18 seconds at wind speed of 5 m/s.



Figure 4. Test tunnel and setups



Figure 5. A pool fire located under the vehicle

he view of the VID system to the flame was obstructed by the vehicle when a small pool fire was located behind the vehicle. It took 100 seconds for the VID system to detect a 0.6 m x 0.6 m pool fire, based on the characteristics of smoke that spread out the vehicle. For a large 1.0 m x 1.0 m pool fire, the

VID system could quickly detect it in less than 20 second. The increase in air velocity in the tunnel had a limited impact on its response time.

As observed in the tests, the simulated passenger compartment fire with the wood crib and foam developed slowly. It took a long time for the visible flame and smoke to be observed outside the vehicle compartment. The VID system detected the fire at 100 seconds after ignition under non-ventilation conditions. Its detection time was reduced to 80 seconds after the longitudinal air flow at the wind speed of 3m/s increased the combustion rate of the fire.

Test results also showed that the VID system was able to detect a small moving vehicle fire at a driving speed of 10 km/h, but had no response to the fire when the moving speed was higher than 10 km/h.

Two tests involving flashing lights on emergency vehicles and headlights of the vehicle were conducted. The light sources were located 20 m and 15 m from the VID detector respectively in the tests. The VID system had no response to these light sources. In addition, the response of the VID system to nuisance alarms could be further improved with its unique function "Delay to Alarm".

A plastic bag was used to cover the camera window during the tests, simulating the oil or water contamination on the camera window. Test results showed that the VID system was still able to quickly detect the small unobstructed fire at 10 seconds, as impact of oil contamination on its flame detection capability was limited. However, its response to smoke was delayed as smoke characteristics were distorted due to the contamination on the camera window.

A metal mesh with 50% obstruction was placed in front of the camera window to simulate fouling of the detector caused by dust and water droplets in the tests. The VID system also quickly detected small unobstructed fire. The detection time was almost the same as that with the clear camera window, showing that such obstructed contamination had a very limited impact on its detection capability.

SUMMARY

AlarmEye® VID system is an integrated safety/security system. Its unique multiple image resources, intelligent image and behaviour analysis enable the system to quickly detect the fires and security incidents, and to minimize the impact of tunnel environments on its performance. Its fire detection capability and reliability have been evaluated in full-scale fire and environmental tests conducted in a research tunnel facility. Test results showed that the fire size, location, longitudinal airflow, vehicle lights and contamination on the camera window had a limited effect on its detection capability. The VID system could respond to a slow moving vehicle fire but not to a high speed moving vehicle fire.

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