WILD FIRE SAFETY: Feed Back on Sudden Ignitions causing Fatalities

Colonel Eric PEUCH

Regional Fire and Rescue Department of Charente-Maritime (France)

Abstract

Sudden and unforseen ignitions happen generaly when a bush Fire is on a weak phase and fire fighters are not very attentive with the danger.

Are there several commun factors to these fatal phenomenons? What is the effect of the wind, of the vegetation, of the slope?

Is the phenomenon due to an acceleration of the ignition porcess or is it due to the sudden ignition of a concentration of inflamables volatil gases?

The feed back of such events causing fatalities can guide our answer.

We will develop the assessment concerning the sudden ignition of concentrated volatile compounds while examining several examples.

On the Power Point presentation, a live video gives a good idea of the phenomenon. Anyway the knowledge of the phenomenon is of a paramount importance in terms of fire safety.

Introduction:

Paradoxically, Fire Fighters appear to be rather safe when facing walls of flames during a defensive operation on a Forest Fire stopping the progression of the fire line or protecting vulnerable installations. Nevertheless, they are aware of the danger. In this respect, they usually implement safety instructions strictly, wearing all their protecting clothing and devices.

However its' not unusual to see firefighters wearing a simple T-shirt, their protecting fire jacket left in the fire engine, the helmet fixed on the belt, sprinkling the vegetation threatened by a small crawling fire growing up hill in the scrub or the bushes. There feel in confidence with the fire. They are not aware of any danger, but, danger lies where they can't see it! Very often fire fronts suddenly increase their speed of spread and blow up consequently to a sudden ignition. This phenomenon caused many fatalities especially in the USA (Mann Gluch Fire, South Canyon Fire…), in Portugal (Frexio de Espada), in Australia, in Italy and in France.

Pro. Domingo Xavier Viegas described a characteristic fire behavior as a " Fire Eruption ". He mathematically managed to model and predict this peculiar behavior. He explains the phenomenon by the convection produced by the fire itself manifested by the sudden occurrence of strong internal winds. He says that it can happen on any fire progressing up hill on a steep slope covered by vegetation.

Several examples of sudden ignitions causing fatalities have been related in the South-East of France during the 90's. On the same way, colonel Picard and doctor Frederique Giroud from the "CEREN", a French Fire-Lab, modeled a few fires trying to understand the phenomenon. He considered it as the "Sudden Ignition of Volatil Distilled Compounds". He noticed that the phenomenon usually happens without wind, on a bumpy relief, generally at the bottom of a canyon , with low vegetation and hot weather. He explains that the fire radiations lights up the concentrated volatiles compounds of the Mediterranean scrub and suddenly blows up.

The purpose of this paper is to describe the phenomenon trough three examples of fires causing fatalities in France. There is no proper scientific analysis although the French Lab, the "CEREN", published original reports about modelisation, but only the observation of a very specific and dangerous phenomenon.

Common Factors in Gas Type Sudden Ignitions

The feed back shows many common factors in the environment of the Fire:

CRITERIA	DATA
Season	summertime
Period	day time
Time	during - or at the end - of a very dry, windy and sunny period of weather
Vegetation	Mediterranean scrub, sparse pine trees, holm oaks, any low vegetation
Relief	small canyons and soft slopes
Wind	Locally slow even if main winds can be strong

We can notice that the ignition never happens at the beginning of the fire. A thalweg (canyon) is always involved. The progression of the fire is rather slow, going up or down hill. These data will be confirmed through the examples shown during the presentation;
The video of the Palasca blaze give an idea of the nature of the fire after the ignition. It can be compared to a hydrocarbon fuel fire. Is it really a Gas Fire? We are predisposed to think that an accumulation of gas from the combustion of vegetation can explain the phenomenon. Consequences must be proposed in terms of individual protection , in terms of Training and in terms of Command.

<u>Common Observations</u>

The observation of the phenomenon shows it is connected to a kind of 'back draft" or "flash-over" even though they cant be strictly considered as similar. One occurs in open air , the others in confined spaces. However both types of phenomenon are very dangerous and can be fatal to the fire fighters. Anyway observations of different wild fires during spells of high wind show that the droughts build up "confined spaces " delimited by different air pressures, especially over canyons.

Generally, the vegetation is hit up by the sun (starting to distil) and by the fire itself (acceleration of the distillation). The distillation gases are heavier than the air (as gasoline vapours). If the wind is weak and the slope not too steep, the fire progresses slowly and burns only one part of the distillation gases. The main part is usually dissipated in the air, or burnt at once in case of a rapid kinetic of the fire. This last assumption can be worsened

when the fire produces its own wind and when the slope is rather steep It can be describe as an "Eruptive Fire Behaviour" (*Dr Viegas, "Anatomy of a Blow-Up" – Wild Fire magazine Sep/Oct 2006*). More commonly, fires described as big blazes induce their own drought, burning the total amount of gases issued by the fuels, producing either fire walls or spectacular trees summit fires and "tongues" of fire.
Unfortunately, in some cases , (*cf "common factors"*), when the shape of the relief allows it, the gases "flow" down hill by gravity and accumulate at the bottom of a canyon. It happens sometimes that the sudden ignition of a concentration of gas is possible during a strong wind period. It seems that the flood of wind, with particular relief configuration-, blowing over a canyon, from a ridge to an other, prevents smoke and gas from evacuating suitably out of the canyon. Gases are enclosed in a virtual space where they concentrate. If the fire fighters enter the zone of concentration when a spark coming from the main fire falls down on the concentration of mix air-gas, fire fighters might be in great danger of blow-up caused by the sudden ignition of an amount of inflammable gas. The Palasca Fire is very typical of this phenomenon. The fire suddenly increased its rate of spread burning 15 acres within 45 seconds! The video shows the symptomatic shape of hydrocarbon volutes in flames filling the relief depression with a rather flat surface that can be described as a "lake of flames".
The phenomenon usually appears during small fires but it can happen when, fighting a big blaze, some fire fighters squadrons deal with secondary fires or "changes of fire" or "side-fires".

First example: The Palasca Fire in Corsica : Abstract of the report about the incident during the Palasca Wildfire, sept. 17, 2000

General frame:
Because of showers during July and a following period of dryness, the Fire season was late and very risky. The fight against several huge wild fires was just finished. : La Restonica (2200 ha) et Vivario (4800 ha) with numerous reinforcements from the continent.
The Fire was a Corsican scrub fire, continued by two fatalities and six casualties involving military and civilian Fire Fighters located around the village of PALASCA, near « the Neru slope". This fire spread on 50 acres. It should have been considered as an ordinary bush fire.
Topography :
The area is a seashore hilly relief. It is situated on the side of the mountain, the altitude is 1,500 ft. The village is situated 7 mile from the sea.
Vegetation :
Low scrub raising up to 2 meters in the bottom of the valley. The vegetation is a newly grown bush-type. This place has been burned down several times before.
The Disaster Area:
The fire traversed a steep sided valley raising a pass. One narrow track (avoiding two engines to pass) runs along the Eastern side of the valley and then reaches the ridge at the Northern Pass. The surrounding area allows 3 places to turn back: the pass, half slope and the entry of the track

The Risky Zone:
There are several thousands of acres of Mediterranean scrub, bushes and pine-trees behind the ridge, in the wind direction, to the North.
There is only one risky point to defend : a Radio-Communication Tower situated near the pass, just by a water tank. There is no residential population in the area, but the Lozari Holiday Camp is located on the other side of the main road . Almost 1000 people stay in this Camp.
Meteorological Conditions:
Sunday, September 2000 17th
Time : Fire starting at 06h57.
Forecast: Maximum level of Risk. The area has never been so dry that year. Strong wind.
Ground Means:
1 platoon from the Corsican Fire Department (4 fire engines, plus command and logistics)
1 platoon from the Military Reinforcement Group
Means of Command :
1Command-Car (Ile Rousse Fire Chief).
1 Command-Car (Head Quarters Fire officer on duty)
Flying Means:
2 Trackers (One initial bombing each).
2 CL 415 on disposal from 08h30
Unfolding of the event:
The original fire did not show any particular difficulty or characteristic. We can notice that the access to the fire is not easy. The reinforcements and the command come from far. The rate of spread is not too fast. The wide canyon were the fire spreads is protected from the wind. The first means on site try to get close to the fire, drawing hoses trough the bushes. The majority of fire engines stopped in front of the fire in order to prevent it from jumping the pass. Because it is rather slow, they prefer joining the fire instead of waiting for it to reach the pass. The fire burned "gently" for 75 minutes increasing the natural phenomenon of distillation of the vegetation. After one hour a few "tongues" of fire appeared in the middle of the canyon although the main fire separated into 2 parts, climbing the canyon by « heat beaming » both sides of the valley.
The ignition of the hot gas occurred on both sides of the track and then lit the middle . Many "tongues" of fire were clearly visible. Then an homogeneous « lake of fire » appeared and lasted 50 seconds.
One fire fighter describes the event : « We were positioned on a track preparing a « stop line* ». The scrub facing us was a least 2,5 ft high. The Sudden Ignition Phenomenon started 500 yards from our fire engine. Within less than a minute the fire reached the engines. Despite ten years of experience as a fire fighter we ran back as rabbits, leaving hoses and vehicles. More than half an Hour later, the temperature was still too high to allow us to move the fire engines blocking the track. Before the blow up the only signal we could detect was a strange feeling of calm and silence."
After a tremendous progression, destroying 15 acres within 45 seconds this « lake of fire » stood still a few seconds and began to decrease. This "up-draft" looked like the roll-over the firemen meet below the ceilings during a confined fire, previously to a flashover.
Then the ground looked like the moon surface.
No one of those who were on the field had ever seen such a phenomenon before in his career.
This Wild Fire was similar to an Hydrocarbon Gas Fire because of the shape of the flames, their homogeneity and the aspect of the surface of the fire (Stabilisation Phase).
2 fire fighters were burned dead, 6 others were seriously injured, one is handicapped.

** "Stop Line": defensive drill to operate facing the fire consisting in positioning a fire engine every 30 yards. 2 nozzles by engines are implemented under the orders of the chief for a short time making a wall of water to stop The fire.*

2nd Example: Suuden Ignition of a Gas Pocket in Southern France: 1 fatality, 1 casualty.

This incident happened in Les Pennes-Mirabeau. It is a village located in Southern France, surrounded by Mediterranean forest and scrub. Wild fires are very usual in this area witch is very dry and subjected to the dry wind coming from the North. The incident happened in February 14, 1989 during a "winter-fire". Two fire fighters were trapped into a blow up causing 1 fatality and 1 serious casualty.

General Frame:
The weather was clear and dry and sunny, the sky was cloudless;
A couple of wild fires happened on the same area.
A strong wind from North-West to North wind was blowing at 80 à 100 km/h (130km/h in gusts).
A fire is slowly propagating downhill towards a small canyon
Vegetation :
Garrigue (Mediterranean Scrub) type with Kermes oak, Cistus, Argeiras, Rosmarinus and a few Pine Trees.
Relief:
Windy platform housing sheltered canyons.
Unfolding of the event:
A fire broke out on the ridge top and burns down hill. Its rate of spread is very slow. Especially when reaching the point of the canyon situated under the wind gusts level.
2 fire engines and a command car arrive on site. They immediately fight the fire with light water means. 3 fire fighters surround the fire when the fire is rather out. Protected from the wind, they beat the ground persuaded to have done with this small fire. However the flames grow up on the other side of a narrow track. 2 fire fighters get closer to it standing on the slope, on a dominating position.
Suddenly a high intensity explosion happened, the entire opposite slope flared up. 2 fire fighters got trapped in a gas-type fire. One was burnt dead, the other one was seriously wounded. The surface of this sudden blow up was at least 20 times lager than the fire size.
Moddeling:
This event has been modelled in order to try to explain the similarity to a gas fire. A mock-up has been assembled to reproduce the study area. It has been noticed that during the simulation process, the fire propagation axis is similar to the axis observed on field. Equally it was noticed that the shape of the canyon prevented the main wind to influence the spread of the fire. Obviously inflammable compounds concentrated in the bottom of the canyon were waiting for over-heat or for a spark.
Analysis:
The investigation for information about volatile compounds emitted by the Mediterranean scrub focused on *Rosmarinus officinalis.*
The method used by the CEREN (South of France Scientific Laboratory):
–Identification of the Volatile Organic Compounds (COV) emitted,
–Importance of the environmental factors (vegetation cover, wind, sunshine…)
–Identification and quantification of the VOC emitted according to the temperature.

The compounds detected were:Tricyclen-Cymenα-Pinene -Limonene-Camphene1-8 Cineoleβ-Pineneγ-Terpineneβ-Myrceneα-Terpinoleneα-PhellandreneCamphorβ-CareneBorneolα-Terpinene

Compounds	
Tricyclene	p-Cymene
α-Pinene	Limonene
Camphene	1-8 Cineole
β-Pinene	γ-Terpinene
β-Myrcene	α-Terpinolene
α-Phellandrene	Camphor
β-Carene	Borneol
α-Terpinene	

PARAMETERS	**IMPACT ON THE NATURE**	**IMPACT ON THE QUANTITY**
Light	**YES**	**YES**
Presence of a vegetation cover	**NO**	**YES**
Nature of the plant	**YES**	**YES**
Sampling height	**NO**	**YES**
Season	**YES**	**YES**
Age of plants	**NOT CHECKED**	**NOT CHECKED**

:

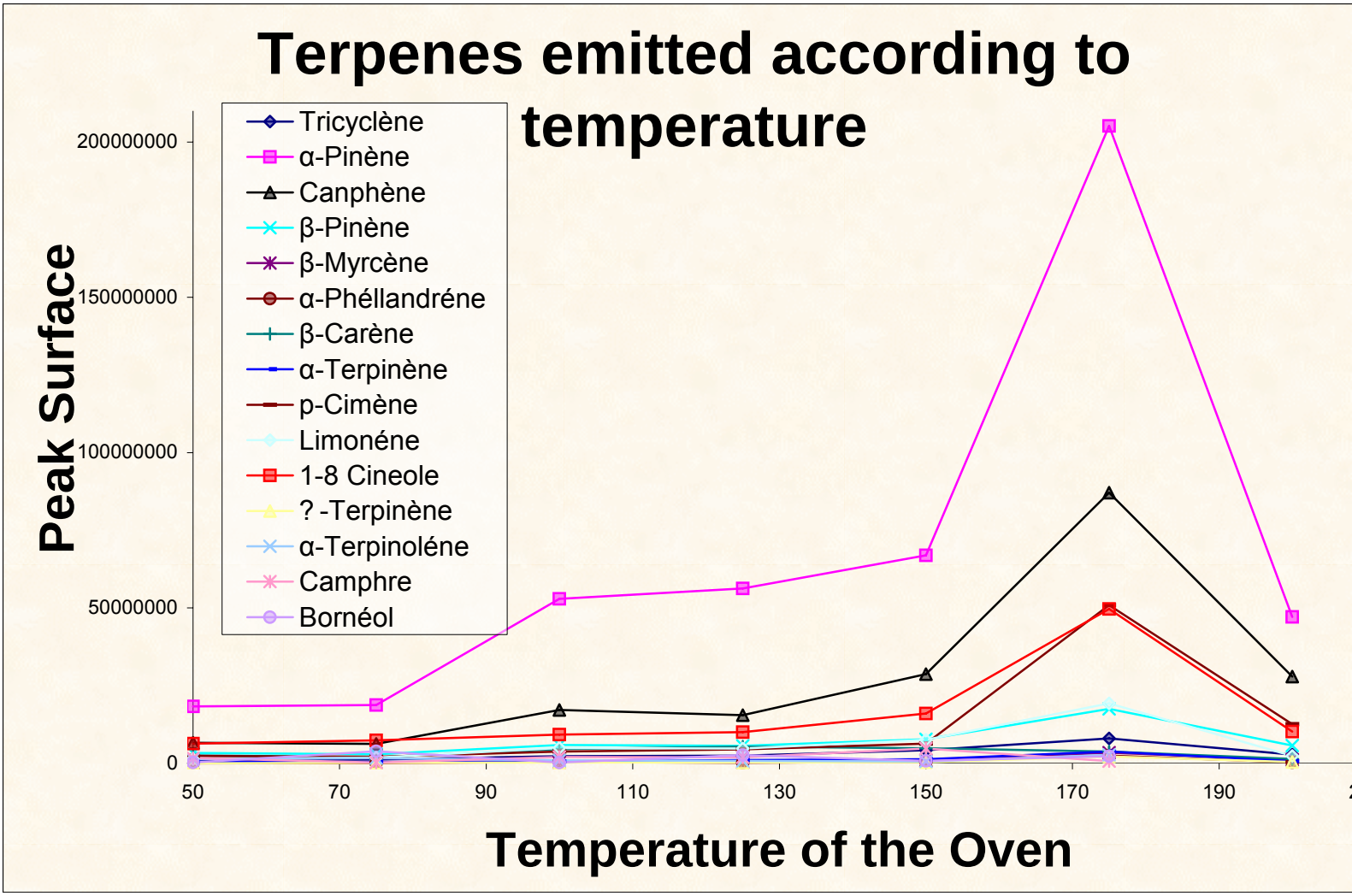

Figure 1— ***Emission of volatil compouds according to temperature.*** ***(CEREN Col Picard, Doc Giroud – France)***

Conclusions:

Influence of the seasons : in summer, the global emission of VOC is more important.
Influence of the wooded cover : the emission is more important when there is no wooded cover.
Influence of temperature : top emission at a specific temperature : 175°C (competition between VOC emission and their degradation).

3nd Example: a Command Car trapped during a Sudden Ignition (fighters behaviour).

During Summer 2004, an accident broke out in the course of a Forest Fire Suppression Action. A Fire Officer was seriously burned.
An investigation was ordered by the Government (National Civil Protection and Defense Department – Ministry of Interior)

Environment: Mediterranean scrub and pine trees area, canyons, cliffs, slopes.
Origin of the fire: a Service Area on the motorway

Fire: low flames going up hill to a pass threatening a few houses. Difficulties of access for the means of fight.
Wind: from the North-East , not too fast.
Means on site: 4 Forest Fire Engines (that is to say 1 « Forest Fire Platoon »)
1 Tanker Engine,
2 Aircrafts on disposal,
1 Airborne Group of Fire Fighters landed by helicopter (that is to say « a Forest Fire Commando » of 6 to 12 Fire Fighters)

Event: the fire progresses up hill through a canyon , means on site are ordered to protect of the houses (engines at the head of the fire), fire suppression (Fire Fighters from the Airborne Group at the tail, Fire Engines on the head, once available)
A few minutes later a sudden extension of the fire happened.
The Fire Officer
1.asks for an emergency Aircraft Bombing over the Airborne Group
2.Orders the Nozzles Holders to flee from the fire
3.Asks the Tanker Crew to attack the fire with its water canon
Unfortunately the action of the canon is not sufficient. A deep black and thick smoke invades the canyon, flames become more active, heat is intolerable.
The Fire Officer decides to ask the crews to take refuge on a burnt area situated out of the dangerous zone. But the way to reach it is not totally visible from his place.
The five Forest Fire Engines go forward on a track just as the fire suddenly catches up the engines in a hidden relief depression., the "Emergency Fire Protection Drill" is implemented and the Mist Protection of each Fire Engine is actuated.
The Fire Officer stands 50 meters from his Command Car. He tries to take it in order to join the group. The heat is so high that he gives up and decides to run to reach the platoon. He has to run across the fire into the smoke.
The Fire Officer is trapped by the fire but he succeeds in reaching an engine after a run. His fellow firemen hoists him in the truck. He is severely burned. His comrades tried to cool him unsuccessfully.
The crew decides to transport the fire officer inside the fire engine to a safe area. They ask for an Airborne Medical Evacuation. Unfortunately the helicopter is on a brake down. Several Fire Engine on duty on a neighbour fire come along quite quickly (guided by GPS).
A Four Wheel Drive Ambulance is in the zone but on the other side of the canyon
The fire passes through quickly enough to keep the personals safe.
The injured Officer is finally transported in a command car to the hospital.
The Officer is deeply burned but he is alive. He is finally transported into a command car to the hospital.
The Officer's car is found completely smashed, the roof is lying on the ground 50 meters away probably because the bottle of air of the breathing apparatus and overpressure system blew up.
It was impossible for the Officer to reach his car because of the sickness of the smoke and the strength of the fire.
He has to abandon his car and find a shelter to save his life. In the hurry, he was able to run to a Fire Engine. He was in a very good health condition.

If he staid into his car, he would have died because of the explosion of the overheated bottle of compressed air.
The planes saved the Airborne Group

The Self Protection Engine Devices were very efficient when all the vehicles were trapped in the fire.

The Evaluation: *about the Fire*
The relief contributed to the progression of fire according two twin factors:
1.wind/slope,
2.canyon/cheminy,
3.pass/venturi effect
The « Tempest of Fire »: sudden inflammation of distilled gazes from scrub in the canyon.
All the Engines were equipped with a Self Protection Kit
Fire Engine were equipped with a GPS device
The Command Car was equipped with Respirable Cockpit System
The Individual Protection Clothing were efficient for most of the fighters except trousers, hood and rank stripe (melted under the Fire Jacket!) of the victim.
The victim did not wear his helmet and his gloves. Deep 3rd degree burns were found on his face and hands.
This type of « small » bush fire is very dangerous and not very well known by the Fire Fighters.
The self protection devices fitted on the Fire Engines have been successfully implemented, protecting the crew from burning.

Analysis:
The Fire Officer did not have a complete view of the situation
His orders were clear and simple
Each engine crew had been trained to the Emergency Drills before going to fire.
The engines were positioned correctly, facing the escape way.
The Control Room reacted correctly after the news of the incident but the operators did not have precise written orders in case of GPS alarm for emergency.
The Firemen of the fire engine (where the victim was sheltered) were Paramedics and took a good care of him even without any medical devices.
No Emergency Engine was available when the accident occurred
The Fire Officer was alone in his Command Car

Consequences:
Self Individual Protection Clothing and Device **must** be worn at any time, on any type of Fire.
The Command Car must not be considered as a safe vehicle, even with an Overpressure System, as long as it has no proper Self Protection System. The Leader Command car must keep close to the Fire Engines. Nobody should stay inside the car in case of Emergency Protection Drill
GPS: Any Fire Engine, Command Car, Tanker… can be easily located especially in case of emergency.
Sudden inflammation must be feared during summer bush fires on canyon-type relief by every fire fighter!
A driver should be appointed to each Command Car (discussion and evaluation of the risk with the Officer, permanent mobility of the car).
Safety must be taken into account at every level of command or coordination.

An emergency evacuation device must stay on disposal within a very brief delay.
A médical (or at least paramedics) ambulance must be affected on site as soon as there are 3 platoons (40 fire-fighters)

Conclusions:
The individual protection clothing must be worn at any time (or must stay close by)
The knowledge of different types of fire must be given by the Fire Department Training Schools, based on the feed back of the previous years.
A permanent look-out should be set up as soon as possible in order to watch the evolution of the fire.
The training to the Self Defence Drills must be practised before leaving to the fire, especially for reinforcements coming from the North.
The Equipment of the Command Cars must be totaly reconsidered.
No one should be alone in an engine. « being alone is being badly accompanied »
The GPS system should be extended to all the Fire Engines. It comprises a emergency button giving the position of the truck. This disposal could be implemented automatically by the Self Defense System.
A emergency medical device must be available at any time
The function of « Safety Officer » must be implemented, on each important fire.
The Self Defense System including should be fitted on any Fire Engine including Mist system, independent emergency pump, breathing air in cabin.

General Conclusion:

This "Sudden Ignition Phenomenon" on wild fires is very risky especially because fire fighters are usually taught to stay below the fire to be safe. Caused either by a eruptive self - acceleration or a sudden gas ignition, the effects can be tragic.
In case of a gas inflammation, the bottom of a canyon is often considered as a shelter while it is strictly forbidden to stay and fight at mid slope dominating fire.
Because the accumulation of gases as described over are unknown and invisible, we can ask the question of the utility of gas detectors worn by every fire fighter.
Actually, the gas detector used by the Fire Departments are regulated on Methane (CH4). The inflammable mix air-gas is different from a gas to an other. In fact the detection of butane or propane- which is rather common in urban areas – is false. Anyway, according to these two domestic gas, it is safer for the Fireman because his detector will start before the dangerous limit. However, if this type of detector is implemented by wild fire fighters we can guess it won't be useful. Either it starts all the time, or it will be left at the fire station! There are so many dangerous compounds in the Mediterranean vegetation vapours (inflammable or toxic) that it would be very difficult to conceive a specific detector.
Anyway any fire fighter must fear this phenomenon. Fire officers in charge of operational organisation must take the phenomenon into account . Leader Officers must be very strict with the fire fighters who have to be forced to wear their individual protection in any situation of fighting.

References (Heading 1 style)

Colonel Claude PICARD Directeur du CEREN CEREN, Sécurité Civile, Valabre, Gardanne.
www.urgence-pratique.com/2articles/medic/art-medical-4.htm - 14k - Toxicité des fumées
Prof. Domingo Viegas « anatomy of a Blow-Up » Wildfire Magazine October 2006
wildfiremag.com/mag/anatomy_blowup/ - 39k