READING THE FIRE

Every fire sends out signals that can assist the firefighter in determining the stage of fire development, and most importantly the changes that are likely to occur. This skill is essential to ensure the correct firefighting strategy and tactics are employed.
Being able to “read a fire” is the mark of a firefighter who is able to make decisions based on knowledge and skill, not guess work or luck.

Fire Indicators

There is a very wide range of information that must be gathered quickly in emergency incidents. This paper will focus on compartment fire indicators.

Firefighters encountering compartment fires must take notice of signs that give an indication of fire conditions.

The indicators can be broken up into 4 broad areas.

1. SMOKE

Colour and density
Volume and location
Height of neutral plane
Pulsations

2. AIR TRACK

Velocity and direction
Flow – turbulent or smooth
Whistling sounds

3. HEAT

Blackening of windows and no flame showing
Blistering of paintwork
Sudden heat build up

4. FLAME

Colour
Volume
Location

SAHF **assessment**

A **Smoke, Air, Heat, Flame (SAHF)** assessment is an important part of the intial and ongoing Dynamic Risk Assessment. It allows the OIC to establish the stage of fire development and to make an assessment of likely changes that could impact on crew safety. It also allows for the development of the most efficient plan of attack. Tasked teams should use the SAHF protocol to assess the risk in their area of operations. This information should be relayed to the Rapid Intervention Team (RIT) and the OIC, so that a more accurate profile of the fire can be developed and maintained.

1. SMOKE

Colour and density:

Smoke colour can vary with the products and the ventilation available. There are some general principles that can be used in that initial size up.

Dark smoke often indicates rich conditions due to restricted air supply.
Where flaming or smouldering combustion is occurring the carbon in the product is released in the smoke and a very dark colour is the result. Where the temperature is low, or oxygen levels are too low to support flaming combustion, the product breaks down (pyrolysis) with out active flaming and most of the carbon remains on the material. This produces a **lighter coloured smoke**. It is important to realise that as the fire develops heat will be transferred to neighbouring compartments, which can result in pyrolysis and an accumulating of fuel laden white smoke.

As the fire progresses the smoke layer will lower and the density of the smoke layer will increase.

As a general guide;
Lighter coloured smoke often indicates that there is an accumulation of pyrolysis products due to increasing compartment temperatures.
Dark smoke indicates rich conditions due to incomplete combustion or a poor combustion process because of the molecular structure of the product.
It is important to look for **changes** in smoke colour.

This photo clearly shows the lighter pyrolysis products on the top left-hand opening (no communication with the other compartments). The top right hand compartment is in communication with the base fire and the dark smoke indicates a rich (ventilation controlled) combustion process.
Photo courtesy Wayne Atkins

Volume and Location.

The volume of smoke can be a guide to the fire size and location. In some cases it can be unreliable and can actually give false indications as to the location, fire size and stage of development. Smoke can travel through concealed voids and shafts and emerge in totally unexpected locations. Most firefighters have experienced a structure releasing large volumes of smoke and later discovering that the actual fire area was quite small or in a totally unexpected location. The basic principle is that the heated smoke will tend to rise vertically. When it reaches horizontal obstructions it will spread out and look for further openings to allow vertical travel. The longer the path of travel, the cooler the smoke will become. This will also result in partial pre-mixing of the air and smoke. As with all fire indicators it is very important not to read one indicator in isolation.

Height of the neutral plane

As the fire develops the **neutral plane** will lower and the density of the smoke gases will increase.
Therefore:

1. A high neutral plane could indicate that the fire is in the early stages of development.
2. A very low neutral plane could indicate very rich backdraught like conditions.
3. A sudden rise could indicate that ventilation has occurred.
4. Gradual lowering could indicate a build up in fire gases and approaching flashover.
5. Sudden lowering could indicate a sudden intensification of the fire

Light coloured smoke often indicates a high percentage of unburnt pyrolysis products.

 

These photos show the lowering of the neutral plane as the fire progresses towards flashover. *Photo courtesy Tim Watkins*

Pulsations

Smoke seen pulsing out of small openings can indicate a **ventilation controlled** fire. This indicates that there are variations in pressure due to limited oxygen supply. As the oxygen level decreases so does the combustion process, which in turn decreases the temperature and the gases contract. When the air is drawn in the fire starts to increase and the pressure rises again until the air is consumed and the cycle starts again. In some cases this could develop into a potential backdraught. Smoke seen pulsing out of larger openings is read very closely with the air track and is covered in the next section.

Air Track

The air track is the movement of air towards the fire base and the movement of the super heated combustion products out of the compartment. The scientific term is "gravity wave" or "gravity current".

Velocity and Direction

When an opening is created, the heated gases will flow out of the top of the opening and cool air will flow in through the bottom of the opening. A total and sudden inward movement of the air track could indicate a potential backdraught event. In some cases this will be followed by an out rush, and seconds later the backdraught.

Flow – Turbulent or smooth

If the air track is slow and **laminar (smooth)** it could indicate that the fire is in the early stages and most likely still fuel controlled. If the air track is **fast and turbulent** (often the neutral plane is lower as well) then this could indicate a working fire that is in the ventilation controlled phase. Vigorous pulsing of the air track is a strong indicator of an active ventilation controlled fire.

Whistling Noises

Whistling noises may indicate that air is being pushed in and out of the compartment through small gaps or openings due to pressure variations. This indicates a ventilation controlled fire. It should be remembered that it might be difficult to notice this with all the background noise.

Heat

The initial assessment should include looking for indicators of the temperature such as:

Blackening and or crazing of windows.

The blackening indicates rich conditions (backdraught potential) and the crazing indicates high temperatures (hot rich combustion potential). Caution should be exercised in opening up under these conditions.

Blistering of paintwork

Sweeping a spray across a door or surface can also be used to test for surface heat. If the door is hot the film of water on the upper section will rapidly evaporate. In some cases it is possible to get an indication of the height of the neutral plane by observing the line at which the evaporation ceases.

Sudden heat buildup

Frequently quoted as an indicator that flashover or backdraught is impending. It often indicates that some form of fire gas combustion has commenced in the ceiling area. This may be difficult for the firefighter to see. This is a very late indicator and should not be relied upon to give adequate warning time. **Temperature checks** can be performed by placing a small burst of water, on a very narrow pattern, into the overhead layer. If the water returns to the ground without any hissing, it is likely that the ceiling temperature is below 100 C in that area. If on the other hand, the water does not come down, and a hissing sound is heard, it would indicate that the temperature is over 100 C. Firefighters can also carefully raise the gloved hand to feel for heat build up. If no excessive heat can be felt through the glove, the bottom of the glove can be slipped back over the palm to expose the skin, and the hand cautiously lifted overhead to feel the heat layer. Regular checks will assist in determining temperature variations and can give the firefighter an indication of the thermal layer.

FLAME

The colour of the flame can give an indication of what product is burning. This can however be misleading, as the same product can burn with different coloured flames depending on the combustion process. For example LPG that is premixed with air will produce a blue coloured flame (due to the presence of CO^2). If the fuel and air are mixed by the process of diffusion, then the flame will be yellow due the presence of carbon particles.

Another example is the combustion of particleboard in a compartment. When the air supply is good it will burn with a yellow flame. If the oxygen concentration is reduced the flame becomes a reddish orange colour.

In a compartment fire, **yellow flames** generally indicate a reasonable air supply. **Reddish orange** flames are an indicator that there is less oxygen available and a rich combustion is occurring. The shape or form of the flame can also give an indication of the type of combustion occurring. The reddish orange flames that result from the rich combustion are often turbulent with a short wave form. The ignition of accumulated pyrolysis products produces a **very light yellow flame, sometimes almost clear**. Amazingly in this case, the wave form is larger and the flames seem very slow. The

formation of blue flames around the neutral plane is said to be due the presence of pockets of carbon monoxide that have formed flammable concentrations.
As with all of the indicators in the SAHF assessment, it is important to look at the initial flame colour and then note any changes.

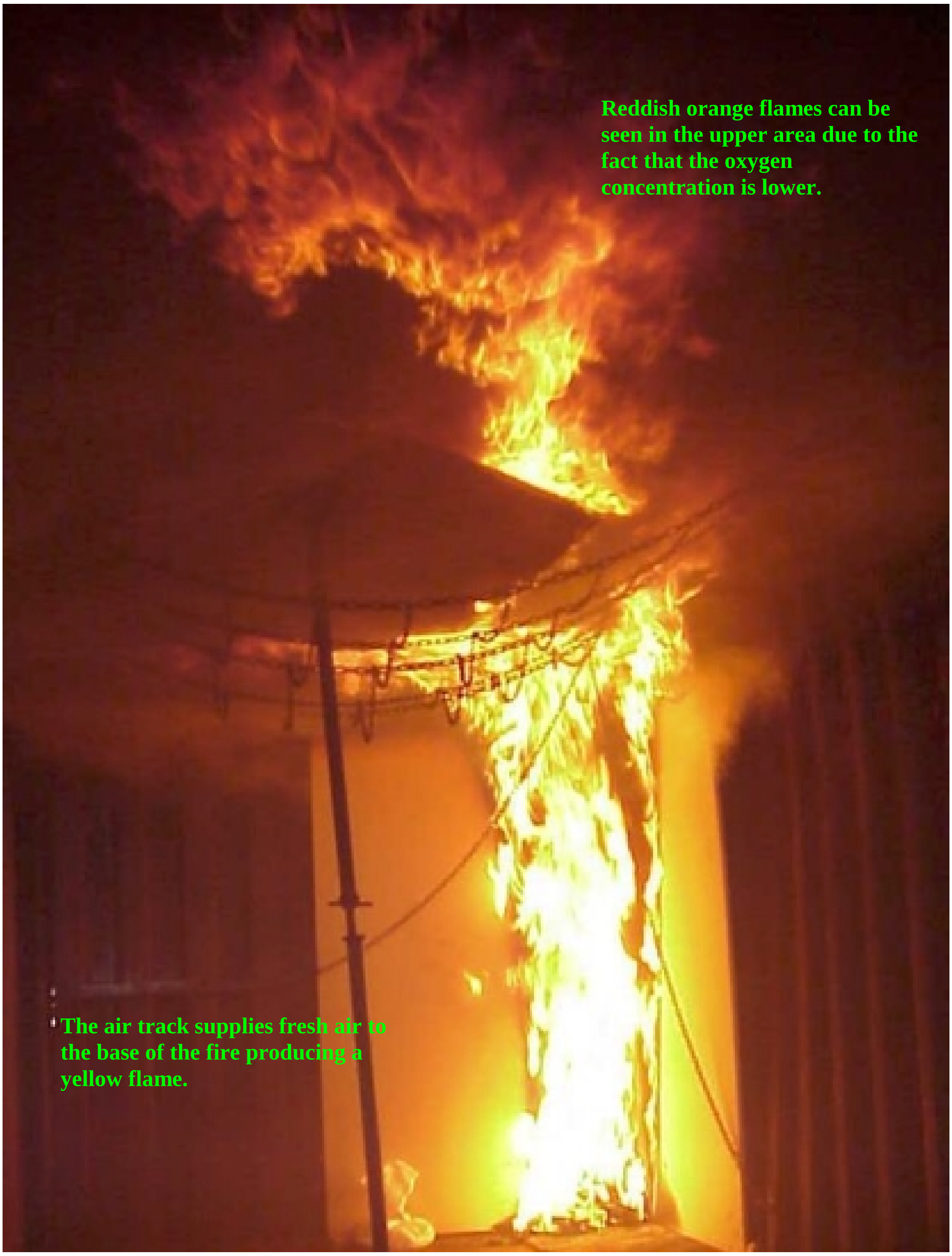

Photo courtesy Wayne Atkins

UK Firefighters undergoing compartment fire behaviour training, the foundation for learning how to "read the fire". *Photo courtesy Ian Roberts*

Dynamic Risk Assessment.

Summary

Accurate size up is essential to ensure that the safest and most efficient method of attack is utilised. In particular, a "Tactical Ventilation" plan cannot be safely developed or implemented until a SAHF assessment is carried out. Emergency risk assessment is dynamic and must be applied until the incident is completed. "Reading the Fire" is an essential element in the development of an overall tactical plan as well as part of the personal risk assessment that should be applied by each team member.

These skills should be developed by a combination of theory, small scale carbonaceous demonstrations, large scale carbonaceous demonstration and if possible carefully controlled single room burns in real structures. Further understanding can be gained by the observation of video footage from actual fires. However, it is only through operational experience and open review that these skills are fully developed.

Swedish Firefighters have mastered the skill of “reading the fire” since the introduction of compartment fire behaviour training in the mid 1980’s. *Photo courtesy Ian Roberts.*

Notes on terminology.

Firefighters are sometimes criticised for departing from scientific terminology. Many of the terms used in this paper may be new to the reader. Where international scientific terms have been applicable, I have used them. Sometimes scientific terms do not serve the needs of firefighters in emergency situations. This may be because the are too long or are not meaningful to firefighters. Many of the definitions used in this paper are designed to simplify the task of communicating the indicators in the urgent and dangerous situations encountered during firefighting operations. Some of these terms originated in Sweden and some have been adapted to suit UK and Australian Firefighters. They have proven very effective in aiding rapid and clear communication of fire conditions in all countries concerned. In particular, I have drawn from the terms and explanations pioneered by Swedish Fire Engineer Krister Giselsson, and UK experts such as John Taylor and Paul Grimwood.

The opinions expressed in this paper are my own and do not necessarily reflect those of my employer.

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Fuel Controlled Fire - Free burning of a fire that is characterised by an air supply in excess of that which is required for complete combustion of the fuel source or available pyrolates.

Gravity Current - also termed gravity wave - An opposing flow of two fluids caused by a density difference (termed by firefighter John Taylor as an air-track). In firefighting terms this is basically referring to the under-pressure area where air enters a building or compartment and the over-pressure area where smoke, flame or hot gases leave.

Over Pressure, Under Pressure and Neutral Plane - In a compartment fire there are a number of regions that develop. Due to the heated gases the region in the top of the compartment there is the effect of a slight positive pressure. A logical name for this region is the "Over Pressure Region". The lower part of the room is cooler and this creates the effect of a slight negative pressure. If the compartment is opened up air will travel in through the "Under Pressure Region" and out through the Over Pressure Region. The separation between these 2 regions is called the neutral plane.

Pulsation Cycle - An indication of the presence of unburned fuel vapours within a compartment with the potential for pre-mixing and a potential explosion - A warning sign for backdraft as smoke 'pulses' intermittently in and out at a ventilation/entry point

Pyrolysis – Chemical breakdown of a substance by the application of heat.

Tactical Ventilation - A concept of safe practice originally introduced during the 1980s and defined by Paul Grimwood as *'venting actions by on-scene firefighters, used to gain control of a fire building's internal environment to the advantage of firefighting and rescue teams working within. Such actions may include attempts to release or direct smoke, super-heated and burning gases from the building by either natural or forced means via vertical or horizontal openings made or existing in the structure. These actions may also include the 'closing down' of a structure in an attempt to reduce the flow of air towards the fire. This tactic is termed 'Anti-Ventilation' by the Swedish Fire service'. It is essential that firefighters remember the most dangerous opening they may create in the structure exists at the point of entry to the building.*

Temperature checks - A technique used by attack teams to estimate the temperature of the over pressure region. This can be achieved by placing short narrow bursts of water onto the ceiling. The firefighter should listen for the sound of water turning to steam and watch for the amount of water that comes back down. If a sizzling sound can be heard and little or no water comes back down we know that the temperature is over 100 C. A longer burst of water can be added and some indication of the temperature can be gauged. The firefighter can also place a gloved hand into the over pressure area to feel for the heat. If this is not too uncomfortable then he can expose a small amount of the wrist area by peeling up the glove. The hand can then be cautiously raised again to fell for heat.

Thermal Balance - The degree of thermal balance existing in a closed room during a fire's development is dependent upon fuel supply and air availability as well as other factors. The hot area over the fire (often termed the fire plume or thermal column) causes the circulation that feeds air to the fire. However, when the ceiling and upper parts of the wall linings become super-heated, circulation slows down until the entire room develops a kind of thermal balance with temperatures distributed uniformly horizontally throughout the compartment. In vertical terms the temperatures continuously increase from bottom to top with the greatest concentration of heat at the highest level.

Ventilation Controlled Fire - Also termed an 'under-ventilated fire' - most fully developed fires that occur under confinement or within a compartment are ventilation controlled and burn under fuel-rich conditions. In these situations the highest temperatures are normally noted at the ventilation openings. The rate of air supply is insufficient to burn all the fuel vapours within the compartment, possibly leading to much external flaming.