

Fire Detection Strategies based on Hazard Analysis in Scottish Whisky Distilleries

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The range of fire detection designs found in distilleries across Scotland can vary greatly. On one hand some of the smaller privately owned distilleries have relatively sparse detection capabilities in place, whereas others, with the increasing corporatisation of the Scottish whisky distillation industry, demand their investments are protected, and so try to ensure their detection systems are in line with good practice with respect to loss prevention.

This paper has two main purposes: 1) to review the hazards that are present in the five main stages of the distillation process (the malting, mashing, fermentation, distillation and maturation of the final product), along with their escalation potentials; and 2) to review the fire detection technologies that are best placed to reduce the risk from these hazards.

Each of the five main stages of the distillation process is examined in relation to the fire hazards posed, and the subsequent strategies available for their detection. It should be noted, however, that all of these stages are not always carried out on the same site and therefore the findings within this paper may in fact apply across a range of different applications.

One of the most efficient ways to reduce this risk is to increase the amount of time available to first responders in mitigating the consequences of such an event, thereby protecting the process unit itself. From an investment perspective, this will reduce the amount of potential down time, and will also protect the often significant volume of maturing whisky which can be stored on site. The impact detector technology selection has on response time is of great significance.

A case history of some notable distillery fires and a review of how these fires could have been controlled through the application of detection technologies widely available today are also included within this paper.

The review of the different fire detection technologies available includes an examination of traditional technologies, such as smoke and heat detectors, in addition to (newer) technologies such as aspirated smoke detection systems. This paper will look at the strengths and limitations of each, for example, aspirated smoke detection systems may be more appropriate where a fast response to a more domestic type fire is required (i.e. the malting/mashing stages).

This paper also contains a detailed review of the areas in a distillery that contain a higher escalation potential with respect to flaming fires (e.g. Still Houses and Bonded Warehouses) , along with a discussion on the differing technologies available for these areas of the process. Such technologies include the more modern, optical flame detection technologies, including Ultraviolet (UV), Infrared (IR) and visual based detectors. As with the other technologies, the strengths and limitations of each are reviewed in order to determine where these detectors can be applied to result in an effective, site-wide fire detection strategy suited to the hazards.

Keywords: Flame Detection, Smoke Detection, Heat Detection, CO2 Detection, Aspirated Smoke Detection, Distillery, Hazard Analysis, Fire Detection.

Introduction

The locating of illicit stills in remote locations was not only to avoid the excise man - safety was a concern even back in the 1800s and is still important now with the hazards inherently present within the distillation process.

Distillery fires are not new, and they are rarely trivial.

The process of distilling whisky includes 5 key steps, Malting, Mashing, Fermentation, Distillation, and Maturation. Each of these stages of production provides differing risks and will require appropriate levels of fire detection, tailored to the hazard the process presents.

When reviewing the Malting and mashing stages, there is no alcohol present, and the fire hazards are typical domestic in nature and therefore the typical smoke/ heat detection strategies will suffice (where the most prominent fire hazards are phenomena including dust explosions, where the role of the fire detection is related to the detection of secondary fires). When looking at fermentation, maturation and particularly distillation, the hazards become a little more suited to the early detection of flaming fires.

During these stages we start to create a hazardous and potentially explosive atmosphere and therefore the standard detection technologies themselves become a spark potential hazard. This is not an issue when using optical based flame detection. This technology is borne out of the oil and gas industry; therefore these devices are literally made for hazardous area applications.

Unlike the oil and gas industry however, the distillation industry still has very little control over some fairly unsafe practices such as venting ethanol sprit into areas which are not designed for such a hazard, and with the distilleries generating revenue from public tours for many months of the year (even when the distilleries shut down due to the, believe it or not in Scotland, warm weather), a very unique set of hazards and consequences presents itself, generating a significant risk which requires mitigation.

With the individual characteristics of the distillation process which makes each and every whisky unique, it is as important if not more so that the building itself is protected from the devastating effects of a fire. This includes the bespoke stills, and also the barrels of liquid gold where maturation occasionally takes place on site. On top of this there is also the responsibility of protecting the personnel and environment. This also includes a protection of the surrounding areas which can and have been affected by fires at breweries and distilleries in the past. While we must protect the environment, the environment itself can have a serious impact on flame spread. Flames can be bellowed by gale force winds (a stranger to no Scottish distillery) which can turn a relatively minor fire into a disaster.

When looking specifically at asset protection, the jewel in the crown of a distillery is the still. It is therefore crucial to achieve a fast response from the fire detection in order to prevent destruction of the creator of the whisky's character. These stills are so unique in nature that their loss/ down time can be felt in market supply 10, 15 and 20+ years down the line.

Hazard Analysis

The process of distilling whisky includes five key stages:

a) Malting;

b) Mashing;

c) Fermentation;

d) Distillation; and

e) Maturation.

Each of these stages of production provides its own set of risks and each requires appropriate levels of fire detection that have been tailored to the hazard the particular stage presents. In the case of the malting and mashing stages, there is no alcohol present. This means that the fire hazards present in these stages are typically domestic in nature and therefore typical smoke/heat detection strategies will suffice (where the most prominent fire hazards are phenomena including dust explosions where the role of the fire detection is related to the detection of secondary fires). This is in contrast to the fermentation, maturation and particularly to the distillation stages, where the hazards become a little more suited to the early detection of flaming fires.

It is also important to note that these last three stages of production lead to the creation of a hazardous and potentially explosive atmosphere. This in turn means that the standard detection technologies themselves become a spark potential hazard. However, this is not an issue when using optical based flame detection. This technology is borne out of the oil and gas industry; therefore these devices are literally made for hazardous area applications.

The following very briefly outlines the primary hazards present at each of the five typical processed involved in the distillation of Scottish whisky:

Malting

In the malting phase, barley is germinated to promote the production of the sugars required to make alcohol. This is then ground down into a grist (after peating in the kiln) which is then used in the mashing phase. Within these areas there is standard domestic type fires associated with the equipment commonly present in many applications. The main difference here is the potential for dust explosion. This is however out with the scope of this review as generally fire detection can do little in the mitigation of these events other than protect against fire spread of the secondary fires. These secondary fires present similar hazards to the domestic type fire previously discussed.

Mashing

During mashing, the grist is mixed with warm water that dissolves the sugars resulting in a mix known as 'wort'. This wort is then used in the fermentation process. Fire hazards during this stage are again mainly domestic and similar in nature to those found in the malting stage.

Fermentation

During fermentation, the first alcohol is created in the form of an ale style wash. This can then be brewed to make beer. The hazards present in distilleries up to this stage in the distillation process, are therefore also present in breweries across the world. Where distilleries differ is that this wash is then transferred into the Wash Still to create the spirit that will eventually become whisky.

The primary hazard related to this area is the high concentration of Carbon Dioxide produced, which is generally vented straight out of the enclosed space. It is, however, credible that this can present a toxic hazard, in addition to the domestic style fire hazards present in this area. The fire hazard would generally be seen as domestic, as at this point the alcohol content is predominantly water, and therefore flaming hazards are unlikely in this area. From a life safety perspective, the potential toxicity from the CO2 and any leak or failure in the extraction system would be the primary cause for concern.

Distillation

During distillation, the creation of high alcohol/ flammable spirit provides a significant hazard. The Still House is also typically a very warm room during operation, meaning that any smoke (of which there would potentially be little visible particulates from a flaming alcohol based fire) would be unlikely to reach ceiling height to activate a smoke detector through either thermal stratification or high HVAC airflow (if present).

As a result of the distillation process, the area is also classified as a hazardous area and falls under the ATEX directive and DSEAR legislation to protect against potentially explosive atmospheres - anyone who has been on a distillery tour will notice the vast majority of distilleries do not allow cameras into the Still House as a result of the potential spark.

This is where the hazard moves from domestic to more of a process hazard, and therefore requires us to have an adequate fire detection system that will actively look for flaming fires, which is also rated for a hazardous environment. A fast response is also pivotal to ensure any event is adequately mitigated against.

Maturation

In order for a spirit to be officially classed as a whisky in Scotland, it legally must have been matured for at least three years. Maturation will typically take place in an oak and/or sherry cask, which helps to create the character of the specific whisky. Obviously, the time in the cask will alter the amount of whisky salvaged at the end of maturation due to the angels' share. This angels' share, in addition to the flammable liquid within the casks, provides a significant fire hazard.

During the maturation phase, we have the storage of flammable spirits in significant quantities, coupled with an environment where robust detectors are required. The predominant hazard in these areas is the ignition of the flammable spirit, resulting in a potentially rapidly spreading fire through the oaken casks being stored. First responders therefore require as much time as possible to protect the area, and the adjacent environment, and salvage as much as possible in the event of a fire.

Historically, some fires in maturation houses have resulted in BLEVE, which creates a significant escalation, and can be very dangerous to first responders and any other buildings/ occupants in the surrounding area. This therefore means a fast response fire detection system is required in this occupancy.

There are many cases of devastating fires during the maturation phase which could have been prevented had the first responders had more time to protect the asset and mitigate the severity of the flame spread. The still house and bonded warehouse represent two areas where passive detection such as traditional smoke and heat detectors provide a delay in detection which can prove costly.

Why Fire Detection is Required - Brief Case Histories

The following represents previous fires within distilleries or similar applications (although is by no means an exhaustive list), and should highlight the importance of a sufficient appreciation of the hazards present and an appropriate fire detection system:

- Cheapside Whisky Bond, 28th March 1960. A fire broke out in the Bonded Warehouse storing over one million gallons of whisky. The specific room in which the explosion took place contained 4.5 million litres of whisky and 140,000 litres of rum. This then resulted in the rupture of some casks, causing a significant BLEVE (Boiling Liquid Expanding Vapour Explosion). This in turn blasted through the walls of the store, which subsequently fell to the ground below. The fire and explosion is still Britain's worst peacetime fire services disaster, killing 19 fire service personnel. Chief Officer Alasdair Hay stated in a memorial in 2014 that: "The scale of the explosion and ferocity of the fire posed a massive threat to neighbouring buildings" (Reference 1). This highlights the potential impact these events can have on the surrounding area and environment and is to this day a pivotal moment in the history of the British Fire Services.
- Heaven Hill Distillery Fire, November 1996. Seven warehouse buildings and some 90,000 barrels of bourbon were consumed as a "river of fire" was created. One account of the fire stated: "Flames leapt hundreds of feet into the air and lit the sky throughout the night" (reference 2). Witnesses reported seeing whisky barrels explode and rocket across the sky like shooting stars ... a two-mile long stretch of the creek that supplied process water to the distillery was set ablaze for a brief time. Depending on the angels' share and taking a rough estimate of £4,000 per barrel of bourbon (estimate based on 200 litre barrels at £20 per litre shop value), that's a loss of £450,000,000 from the bourbon alone.
- This was one major accident in which the surrounding environment played a significant role in the escalation of the event. 75mph gusts bellowed the flames, providing the perfect storm for flame spread and, as the buildings burned, the bourbon leaked out in to the drainage system which created the often described 'river of fire', which assisted in escalating the fire even further.
- Wild Turkey Bourbon Fire, May 2000. Warehouse fire destroyed 17,000 oaken barrels - good news for the bourbon barrel manufacturers, but a significant financial loss for the distillery. As the whisky burned, it flowed from the warehouse and ignited trees in close proximity to the warehouse. This is an example of the impact the surrounding environment can have on event escalation where appropriate mitigation measures are not put in place, thereby increasing the likelihood of containment of the fire.
- This event also caused the temporary shutdown of the nearby water treatment plant and led to the spillage of whisky into the Kentucky River. This in turn caused the largest fish kill in Kentucky history (Reference 3).
- Langley Green Distillery Fire, November 2012. Mixing of chemicals results in a fire which burns all night, leading to local residents being relocated due to the intensity of the flames and risk of secondary explosion. In the resulting escalation, 200 homes were evacuated as over 100 firefighters fought the blaze (Reference 4).

- Burghead Maltings Fire, February 2015. Fire in the kiln area containing 60 tonnes of grain. Fire brigade required high elevation vehicle due to fire spread and worked tirelessly through the night, remaining on scene into the following day to ensure secondary fires did not present a problem. Due to the location of the fire, emergency services from the surrounding areas of Fochabers, Forres, Elgin and Lossiemouth were able to mobilise quickly and control the escalation of the event. This shows how effective a fast response can be in preventing significant escalation of a potential fire event, which is precisely the action required from fast response detection devices, detecting at a point where the fire is far easier to control by those on site (Reference 5).
- Silver Trail Distillery Explosion, April 2015. Explosion resulting from an over pressurised still caused a fire that destroyed the facility, killing one and injuring others (Reference 6). While the fire detection could have done little to prevent the initial explosion (cited to have been caused by an internal plate having been tack fitted rather than fully welded, resulting in loss of integrity of the relief valve and thereby causing the still to explode), the escalations of secondary fires caused by the explosion are what the detection system would be intended to help mitigate.
- Crown Royal (Waterloo warehouse) fire, 1993. The exception to the rule that sometimes a fire can be good for business. As a result of the destruction of a significant volume of maturing whisky, Crown Royal ended up creating the XR (Extra Rare) whisky range from the barrels salvaged from a fire at its Waterloo Warehouse. This can still be purchased today at a significantly inflated price - one way to make a good thing out of a tragedy! (Reference 7)

Distilleries are typically classed as a top tier COMAH site due to the process and also the quantity of flammable fluids stored on site. Currently, under the ATEX Directive, with respect to explosive atmospheres in the workplace (Reference 8), brewers and distillers have a hierarchical responsibility: do not have a flammable atmosphere; if you do, do not ignite it; if you do, do not hurt anyone. One way to achieve compliance with this third requirement is the application of optical flame detection. Traditional forms of fire detection (smoke and heat) are not reliable in detecting fires before they are a credible threat to human life, and are historically asset protection devices. Optical flame detection, however, manufactured to protect personnel offshore, are designed to protect personnel from the start of the event through their fast response to even relatively small flaming fires.

What can be Used, and Where

Traditional Smoke/ Heat Detectors

During the early processes in a distillery, there are credible arguments for having traditional smoke/ heat detectors. The environment lends itself to their application i.e. it is not a hazardous environment, and the fires expected are typically domestic in nature. The primary hazard at the malting stage is that of a dust explosion from the grist/ fine particles that can ignite either within the equipment itself or the environment. In an occasion like this there is very little a fire detection system can do for the initial event. However, mitigation of secondary fires is still important, and with the potential for escalation in these areas being relatively low, the response times provided by conventional smoke/ heat detection systems are suitable for the reduction of risk to As Low As Reasonably Practicable (ALARP). The main drawback of applying these detectors, however, is in the response when installed in applications with an environmental impact that can inhibit detection. This includes areas with high airflows or where thermal stratification occurs. High airflows can occur in the malting phase due to either HVAC or the opening of windows to allow the natural air into the malt floor in order to add character to the flavour. Thermal stratification can also occur in the mashing/ fermentation phases due to the increased heat at ceiling height during these processes.

Aspirated Smoke Detectors

Where a faster response is desired, but the hazard does not lend itself to the detection of flaming fires, aspirated smoke detection systems are becoming increasingly popular. These devices combat against many of the issues related to domestic smoke and heat detectors. As an example, these can nullify the effects of HVAC/ naturally driven airflows that would direct the smoke/ heat away from the detector head of conventional devices. The aspirated devices can also combat against thermal stratification, which can be a problem in the mashing/ fermentation phase. This is where the heat generated from the process will rise in the room, and therefore the cool smoke from the fire may not reach the smoke detector until the fire has grown to the point it can be difficult to control. At that point, the mitigation function of the device has lost its effectiveness.

The aspirated units operate through actively drawing the air from the room into the unit itself. The sampling points are distributed by a pipe network, which means maintenance of the system can be carried out completely from the unit itself at ground level. This is irrespective of how complex or highly elevated the pipe network is throughout the room.

These units are more expensive than the more conventional smoke or heat detectors. However, with the added benefit of a fast response to a smouldering/ incipient fire, coupled with the ease of maintenance, it is recommended that aspirated smoke detectors be applied in the malting and mashing phases of production.

CO2 Point Gas Detectors

During the fermentation process, significant quantities of CO2 are produced and are vented to a safe area. If, however, this system fails, we have the potential for a toxic hazard in addition to the standard domestic type fires as previously discussed. It would therefore be prudent to provide a leak detection system to protect personnel against this potential toxic hazard.

It is, however, important to note that the application of a CO2 point gas detector can also double as a fire detector when calibrated correctly. As a typical fire will provide significant quantities of CO2, these devices will detect the CO2 produced in a fire as well as the CO2 by-product of the fermentation process, providing both a toxic and a smoke detector in one unit. This can therefore reduce costs and maintenance, by installing only one unit for both areas of mitigation.

Optical Flame Detection

Historically where fire detection has been applied in distilleries, these have been traditional domestic type detectors comprising of smoke or heat detectors. The issue with these devices is their passive nature in which they rely on the smoke or the heat to reach the detector. The problem with this is that there are environmental aspects of distilleries which combat against this (as previously discussed).

An example would be the high ambient temperatures of the still house, where the smoke from a fire that is buoyant and rising will have to fight against the already high temperatures which have also risen, resulting in thermal stratification pushing against the rising smoke. Subsequently, this means the detector will not go into alarm until the fire has developed even further, to the point the smoke temperature exceeds that of the environment. In a large open space such as a still house, this can lose precious minutes of first responder time.

Another issue affecting the traditional detection technologies is the fact that the character of a whisky is created by the Scottish climate and air, generally meaning many of the areas of a distillery will have openings to the elements. This will increase the exposure to cross flow dynamics from either the winds or HVAC driven flows. This can disrupt the flow of smoke and again mean the smoke may not reach the detector until the fire develops, thereby delaying the detection time in an area with a significant escalation potential.

The natural solution for this is to apply active devices which 'seek' out the fire. As a result of this, it is credible to reduce the total number of devices where a large field of view is achieved by the flame detector, compared to the standard prescriptive grid of passive smoke or heat detectors.

The real benefit of optical based flame detection is in the response time. With detection to even a relatively small fire (40 kW radiant heat output), these devices can respond anywhere between 1 and 10 seconds. This gives first responders a far greater chance of controlling the fire before any real damage can be done.

If optical based flame detection is selected, there are a number of different options available. These comprise either the radiant or visual based families, each with their own strengths and limitations. When looking at the distillation process, visual based flame detection therefore provides many benefits that make it the technology of choice for this application.

From an operational standpoint, the reliability of these devices is typically very high. This is true even when exposed to the harshest of environments (being originally developed for application in the North Sea Oil and Gas Industry). Visual based flame detectors are not affected by the same stimuli that can deteriorate the traditional detection technologies i.e. steam creating false alarms from smoke detectors and any dirt/ grime from the environment creating a fault in the device. The devices are also inherently applicable for application within the hazardous/ explosive environment of distilleries.

Maintaining the devices is also relatively straight forward. This can be done using remote test torches that allow the operator to test the device from the ground up to 8m away from the device.

Other forms of optical flame detection, based within the radiant family of detectors (either Infrared or Ultraviolet based detectors), can be affected by modulating radiation that is typically present within the warmer areas of a distillery. This can send these detectors into false alarm, or desensitise/ blind the detector to a potential fire, depending on the unit selected. As visual based flame detection operates in the visual spectrum, the technology is not affected by these stimuli.

Steam can also blind radiant based forms of optical flame detection. However, as the attenuation of radiation in water is 1000 times less within the visual region of the electromagnetic spectrum than that of the radiant region, visual flame detection is the obvious choice to ensure reliable detection is achieved.

One of visual flame detection's greatest assets, however, lies within the device itself. Historically, due to the intense heat of distillery fires, the cause of a fire can be very difficult to determine as much of the evidence is destroyed. In fact, the causes of many distillery fires remain 'undetermined.' With visual flame detection, the on-board camera will provide a recording, acting as a 'black box' to show how the fire started and how it developed. This is subsequently recorded to the on-board SD card for post-incident review. This provides investigators with invaluable evidence post-incident and is one of the most unique and beneficial aspects of visual flame detection.

Conclusions

It is clear that the hazards inherent in the distillation and associated industries present a very unique set of circumstances. As a result of this, it can be concluded there is no clear strategy that can be applied prescriptively throughout assets of a similar nature, and that each individual site should be designed in a performance based nature, born out of what the desired performance target may be.

Through examination of the hazards present at each of the main stages in the production of whisky, we see that there are technologies available relating to the detection of fire that are best suited to certain areas of the asset. This is a result of there being no such thing as the perfect fire detector.

In those areas where a domestic type fire is to be expected (Malting/ Mashing/ Fermentation), conventional type smoke/ heat detection will likely be the primary form of detection. This is due to the hazard analysis showing reduced escalation potential, coupled with an appropriate low cost of such devices.

Where the hazard may present an increased escalation potential, but does not yet present an escalation potential from the point of view of a flaming fire (for example where dust explosions could provide a credible hazard), certain aspirated smoke detection systems may be more beneficial.

Where flaming fires become credible and where the escalation potential is high (Distillation and Maturation stages), this is the application where flame detectors ought to be considered. Even within this form of detection there are many technologies from which to choose from. Out of the specific environment, and anticipated flame type, visual flame detection appears to be the optimal choice in these circumstances.

Following these recommendations, when tailored to the specific asset in question, the appropriate fire detection can aid in reducing the overall risk to an asset due to the potential for reduction in the consequence resulting from a potential fire event.

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